THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE ATOKA FORMATION ON THE NORTH SIDE OF THE McALESTER BASIN

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Norman, Oklahoma

1957

THE ATOKA FORMATION ON THE NORTH SIDE

OF THE McALESTER BASIN

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ACKNOWLEDGMENTS

Dr. Carl C. Branson directed this dissertation problem. Dr. George G. Huffman, Dr. E. L. Lucas, Dr. Doris Curtis, and Dr. Reginald Harris contributed helpful advice and information. The Oklahoma Geological Survey employed the author as field geologist during the summer of 1954. Assistance was rendered in the field by Richard Beveridge during the month of June in 1953; and Mr. A. H. Hanson of Muskogee, Oklahoma, spent a portion of one day in the field with the author, directing his attention to several fossil localities in the Atoka formation.

Mr. Irwin Gold photographed the thin sections and the fossils, Mr. June D. King took some of the field photographs, Mr. Raymond Kunc instructed the author in certain procedures of drafting, and Mr. Roy Davis and Mr. Kent Cregg assisted with much of the drafting.

The author's wife, Ruth, assisted in certain phases of the field work, typed preliminary drafts of the dissertation, and continually encouraged the author during all phases of the dissertation program.

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CHAPTER I

INTRODUCTION

The Atoka formation was named by Taff and Adams in 1900 (p. 273). Although the town of Atoka in southern Oklahoma was apparently intended as the type locality, the type locality was never specifically designated and is, therefore, only inferentially identified. A measured section of Atoka strata from the vicinity of Atoka was not published in the definitive paper, but mention was made of approximately 7,000 feet of Atoka strata that lie above the Wapanucka limestone of Morrowan age and beneath the Hartshorne sandstone of Middle Pennsylvanian age in this area (*ibid*.). Later studies have indicated that the selection of Atoka, or vicinity, as the type locality was not altogether felicitous, inasmuch as the section there is highly faulted. Thicker sections, less complicated by faulting, are present in many areas of eastern Oklahoma and western Arkansas.

In Arkansas, rocks equivalent in age to the Atoka formation were named the Winslow formation by Adams in 1904 (p. 29), for the village of Winslow in Washington County. Croneis (1930, pp. 90-91) later recognized the age equivalence of much of the Winslow formation and the Atoka formation and applied the name *Atoka* to these strata because of its prior usage by Taff and Adams (1900, p. 273).

The thickest sections of Atoka strata are in the McAlester Basin and Arkansas Coal Basin in east-central Oklahoma and west-central Arkansas, respectively. In this area, the Atoka formation is present in aggregate thicknesses of several thousands of feet. Croneis (1930, pp. 118-132) published a measured section from Perry County, Arkansas, where the thickness of the Atoka formation was reported as exceeding 9,479 feet. Hendricks and Parks (1950, pp. 70-71) referred to thicknesses of approximately 9,000 feet of Atoka strata in the southern part of the Fort Smith district in southern Sebastian, northern Scott, and southern Logan Counties, Arkansas. In the southern part of the Oklahoma Coal Basin in southeastern Coal County, Oklahoma, the Pasotex No. 1 Underhill well in sec. 26, T. 1 N., R. 11 E. penetrated 7,800 feet of Atoka beds (Ardmore Geological Society, 1954, p. 4).

In most areas of exposure, the Atoka formation consists of shale and sandstone beds, with occasional thin limestones interspersed through the section at widely separated intervals. The sand-shale ratio is small (i.e., 1 or less) in the area of the McAlester Basin, but increases to 2 or greater on that portion of the shelf to the north and northwest in Seminole County, Oklahoma (Dickey and Rohn, 1955, p. 2312). Sand-shale ratio studies of the Atoka formation by Dickey and Rohn (_ibid._) indicated that the major part of the Atoka sediments of the northern shelf area of the McAlester Basin was derived from land areas to the northwest, north, and northeast. Croneis (1930, p. 117) pointed out that sandstone becomes more abundant toward the north and east in Arkansas, whereas the shale component increases southwestward into Oklahoma. Chert-pebble conglomerates of the area near Wagoner, Oklahoma, were apparently derived from outcrop areas of "Boone" chert in the Ozark Uplift, a positive tectonic feature which was subjected to gentle uplift in early Atokan time. This time of uplift, correlative with the main Wichita orogeny in southern and southwestern Oklahoma, is indicated by the pronounced unconformity separating Atokan rocks from Morrowan strata in the shelf area of northeastern Oklahoma, as well as by the local chert-pebble conglomerates and conglomeratic sandstones in the lower Atoka strata of the northeastern Oklahoma shelf.

The Ouachita Trough in southeastern Oklahoma subsided during Mississippian time to receive great thicknesses of Stanley shale and Jackfork sandstone and moderate thicknesses of Johns Valley shale. The recognition of an Upper Mississippian, Caney, fauna in the Johns Valley shale (Cline, 1955, pp. 26-27) indicated a Mississippian age for the Johns Valley shale and also for the Stanley-Jackfork sequence.

During Morrowan time, a thousand feet or more of sandstones and shales were deposited. In the Ouachita Mountains, the rocks containing the "Morrow fauna" of Honess (1924, pp. 14-18) are included in this sequence, indicating the possibility that the whole sequence of strata above the Johns Valley shale in the Ouachita Mountains is of Lower Pennsylvanian, Morrowan, age. It is possible that no strata of Atokan age are present in the mountains south of the Ti Valley fault. A gradational contact exists between the Stanley and Jackfork sequences of strata, and a similar gradational contact apparently characterizes the interval between the Jackfork group and the overlying Morrow strata (Croneis, 1930, pp. 115-116; Honess, 1924, p. 22).

During Atokan time, the axis of greatest subsidence, or foredeep, was the McAlester Basin. The thick sedimentary record of Atokan strata in that area suggests that the uplift of the Ouachita Mountains occurred in post-Morrowan, pre-Atokan time, and possibly was synchronous with the main Wichita orogeny.

In the Muskogee-Porum area, which is, in general, that area south and west of the Arkansas River and north of the Canadian River in a portion of Muskogee and McIntosh Counties, Oklahoma, Wilson subdivided the Atoka formation into six sandstone members with associated unnamed shales (Wilson, 1935). Names were assigned these members, and the associated unnamed shales were each designated by the letter "A", with the appropriate sequential numerical subscript. In this area, the Atoka formation is approximately 600 feet thick, and the members are, in ascending order, the Coody sandstone, the A_1 shale, the Pope Chapel sandstone, the A_2 shale, the Georges Fork sandstone, the A_3 shale, the Dirty Creek sandstone, the A_4 shale, the Webbers Falls sandstone, the A_5 shale, the Blackjack School sandstone, and the A_6 shale (Wilson, 1935).

The map accompanying the present report portrays the distribution of the Atoka formation and its recognizable members in the outcrop areas of Wagoner and Mayes Counties, Oklahoma. This map was prepared in the field with the aid of air photographs. Mapping was done on transparent acetate overlay sheets on the photographs, with the information subsequently being transferred to the working copy of the field map. An ensuing program of editing and redrafting resulted in the final map.

Early in the course of mapping the Atoka formation in Wagoner and Mayes Counties, it became evident that facies changes and thinning of the section north of the Arkansas River made it unwise to attempt a perfect identification of the rapidly thinning shelf facies section with the members of the Muskogee-Porum area. Fortunately for the mapping program, the Webbers Falls member, with its siltstones, limestones, and shales, provided an easily identifiable and fairly persistent marker unit, which was traced from a short distance north of the Arkansas River in southern Wagoner County to a locality one mile north of Chouteau in Mayes County. The tracing of this persistent unit also provided a stratigraphic reference by means of which identification of the overlying Blackjack School member was possible. The middle Atoka section, identified as Georges Fork and Dirty Creek sandstone members in the Muskogee-Porum area, could not be readily differentiated into these two units north of the Arkansas River and they are, therefore, mapped as one unit. In like manner, the lower Atokan Coody and Pope Chapel sandstone members are at few places amenable to precise differentiation north of the Arkansas River, and are also mapped as one unit. Highly refined petrographic studies by future workers may yield a basis for more accurate delineation of these units, but the nature of Pennsylvanian sedimentation militates against this possibility.

Weirich (1953, p. 2032) demonstrated that the approximate position of the hinge line between the subsiding McAlester Basin and the shelf area to the north was through central Hughes County, north-central McIntosh County, and possibly, by extension, through southern Muskogee County north of Warner. The Atoka section, as described by Wilson and Newell in the Muskogee-Porum area (1937, pp. 24-35), is thus noted to be a section deposited on the approximate margin of the McAlester Basin in

Atokan time. By contrast, the section of Atoka strata in Wagoner and Mayes Counties to the north is definitely of shelf facies, deposited on the fairly stable shelf, marginal to the basin, in Atokan time. The difficulty of extending the precise member designations of the Muskogee-Porum area to the units of the shelf facies is aptly expressed by Weirich, who, in discussing the Atoka shelf facies, in general, stated (1953, p. 2031):

> The sandstones over the shelf area are patchy. They subdivide into vertical multiplicity, and perform such tricks of disappearing, reappearing, subdividing, and piling into thick masses as to baffle the most experienced investigator.

In addition to mapping the Atoka formation in the outcrop areas of Wagoner and Mayes Counties, the general nature of the Atoka formation, as portrayed in various phases of its stratigraphic, petrographic, sedimentational, and paleontologic aspects, was studied in portions of Cherokee, Muskogee, Sequoyah, Craig, and Coal Counties.

A generalized distribution map of areas of Atoka outcrop in northeastern Oklahoma accompanies this report.

Comparison of data collected in the field with data secured by other workers concerning rocks and faunas of Atokan age in other parts of the world was facilitated by a study of available literature.

Within the state of Oklahoma, the Lake Murray formation, constituting the lower portion of the upper part of the Dornick Hills group of the Ardmore Basin area, is believed to be correlative with the Atoka formation of the McAlester Basin, and the northeast Oklahoma shelf areas. The Lake Murray formation includes the following members, in ascending order: Bostwick conglomerate, Lester limestone, and Frensley limestone (Branson, 1956, p. 15).

In north-central Texas, the Smithwick shale and the Big Saline limestone member of the Marble Falls limestone, are believed to be of Atokan age (Plummer, 1943, pp. 47 and 52: Abilene Geological Society, 1950, chart following p. 11); and in the Marathon region of western Texas, the Haymond formation, which carries giant boulders similar to those in the Johns Valley shale of the Ouachita Mountains of Oklahoma, has been assigned to the Atokan series (Moore and Thompson, 1949, pp. 288-289).

North of Oklahoma, in Kansas, rocks of Atokan age are questionably present. Moore, et. al. (1951, p. 102) reported that limestones and shaly limestones attaining 500 feet in thickness in the subsurface of southwestern Kansas have been assigned to the Atokan series.

In the Franklin Mountains of the El Paso region of Texas, a portion of the Magdalena formation is believed to be of Atokan age (Nelson, 1940, p. 166). Thompson (1948, p. 68) suggested that the Derryan series of New Mexico may be the approximate equivalent of the Atokan series.

In other western states, Atokan rocks are represented in the Four Corners region of southwestern Colorado, southeastern Utah, northwestern New Mexico, and northeastern Arizona (Wengerd and Strickland, 1954, p. 2167). Atokan equivalents are believed to be present in central Colorado, Wyoming and Montana (Mundt, 1956, p. 1929), the Williston Basin area (McCabe, 1954, pp. 1957 and 2007), Idaho, Utah, Nevada, northern Arizona, and southern California (Moore, et. al., 1944, Plate 1).

Recent work by Dott (1955, pp. 2219 and 2286) demonstrated that the lower portion of the Tomera formation and possibly the uppermost part of the Moleen formation in the Elko area of northeast Nevada are of Atokan age. Both zones contain Fusulinella.

Portions of the Carboniferous section in Oregon, Washington, and Alaska may belong to the Atokan series (Moore et. al., loc. cit.).

In eastern North America, the thick Kanawha portion of the Pottsville series of Pennsylvania, West Virginia, and Maryland, and part of the Pottsville series of Ohio, Indiana, and western Illinois contain Atokan equivalents (Moore, et. al., loc. cit.). The Caseyville formation is Atokan in age, in part, in southern Illinois and western Kentucky (Wanless, 1956, plate 1), while the Breathitt formation of Kentucky, the Saginaw formation of Michigan, and the Mansfield formation of Indiana, were deposited, in part, during Atokan time (Moore, et. al., loc. cit.).

In the Acadian Province of North America, where thick sections of Pennsylvanian sediments accumulated, Atokan equivalents are represented by the Cumberland group of Nova Scotia and the Lancaster formation of New Brunswick (Moore, et. al., loc. cit.).

More specific references to Atokan age equivalents and their fossils will be made in subsequent portions of this paper.

In Europe, rocks of Atokan age comprise a portion of the Upper Westphalian, or Moscovian, as do portions of the older Morrowan section and all of the overlying Desmoinesian (Moore, Lalicker, and Fischer, 1952, p. 37).

Rocks of Atokan age are perhaps best studied in Europe in the area of Russia west of the Urals, inasmuch as the Carboniferous strata are essentially undisturbed in this area.

According to Gignoux (1955, p. 166), Fusulinella appeared in the

Dinantian of Europe, which has been correlated with the Mississippian system of North America. However, since Gignoux referred to a paper by Thompson (1935) as a basis for this statement, the correlation is perhaps in error, since Thompson definitely defines Fusulinella as an Atokan and Lower Desmoinesian fusulinid, which, if synchronous in Europe, would assign it to the Upper Westphalian or Moscovian. Fusulina, a Desmoinesian index fusulinid in North America, appeared in the Moscovian of Europe, thereby suggesting the equivalence of a portion of Upper Moscovian to the Desmoinesian section of North America.

Gignoux (1955, p. 168) noted that the base of the Upper Westphalian in Europe is characterized by the cephalopod Gastrioceras, which accords with the zone of Gastrioceras in the Morrowan section of North America (Unklesbay, 1954, p. 94).

Thompson (1942, p. 28) noted that rocks of Atokan age have been recognized in Peru, Spain, Egypt, Spitzbergen, Mongolia, China, and Japan, as well as in Europe and North America.

CHAPTER II

STRATIGRAPHY

The Atoka formation in the Muskogee-Porum area has been subdivided by Wilson (1935) into six sandstone members, which are, in ascending order, the Coody, Pope Chapel, Georges Fork, Dirty Creek, Webbers Falls, and Blackjack School. An overlying shale unit is associated with each member. The distribution of each member in the Muskogee-Porum area is shown on the geologic map accompanying the report on that area by Wilson and Newell (1937, pp. 24-35).

Elsewhere in Oklahoma, few attempts have been made to subdivide and name the members of the Atoka formation in the areas of outcrop; but in Arkansas, Henbest (1953, pp. 1946-1947) named the Greenland sandstone member of the lower portion of the Atoka formation, with the type locality noted as the village of Greenland in Washington County, Arkansas. Exact correlation of the Greenland member with the Atoka units of the Muskogee-Porum area is admittedly difficult and perhaps impossible, but the occurrence of the Greenland member in the lower part of the Atoka formation and its lithologic description as noted by Henbest seem to suggest a tentative correlation with the Coody sandstone member of the Muskogee-Porum area.

Henbest (1953 pp. 1946-1947) described the Greenland sandstone member as a

> silty, ripple-marked flaggy sandstone with shaly partings. Locally, marine quartz-gravel conglomerate, which alters on exposure to contorted limonite-cemented sand, lies at the base of the unit or interfingers with it at higher levels. At some places lenses of marine quartz-gravel sandstone that are more or less massive or cross-bedded either interfinger or partly cut out parts of the member.

Henbest (1953, p. 1947) referred to a few cephalopod specimens which have been found in the Greenland member in and near the SE¼ sec. 36, T. 14 N., R. 30 W., although generic and specific identifications are not indicated. Miller and Downs (1948, p. 672), however, listed *Mooreoceras*, *Knightoceras oxylobatum*, *Pseudoparalegoceras williamsi*, and *Winslowoceras henbesti* from the Atoka formation in sec. 13, T. 13 N., R. 30 W., somewhat over two miles to the north in the area of the Winslow Quadrangle.

Wilson and Newell (1937, p. 27) described the Coody sandstone as "a massive, buff sandstone, locally conglomeratic." and mentioned that the Coody sandstone "is especially noteworthy for the marked development, at least locally, of chert pebbles, and coarse, gritty sand." They recorded the thickness of this member as 15 feet in some localities, to a maximum of 115 feet in other places (*ibid*., p. 28). Thin ferruginous limestones and thin shales are also mentioned as occurring in the Coody section (*ibid*.).

A cephalopod fauna from the Coody sandstone in sec. 33, T. 15 N., R. 20 E., on Braggs Mountain, is listed (*ibid*., p. 27).

The present study of the Atoka formation in Wagoner and Mayes Counties has revealed that the Coody-Pope Chapel sequence is highly variable in thickness and lithology. In the SW¼ NW¼ sec. 20, T. 18 N., R.

19 E., approximately 100 to 150 yards north of the Wagoner Pumping Station, on the shore of Fort Gibson Lake, the basal Atoka section consists of approximately 15 feet of chert-pebble conglomerate, with large elliptical dark red ocherous clay pods and pellets at the base near the contact with the underlying Morrow group. The chert pebbles have an average diameter of 0.5 to 0.25 inch, are sub-angular to sub-rounded, and are firmly bonded with a hard siliceous-ferruginous cement. Crinoid columnals and the colonial coral, Pleurodictyum, have been noted in this conglomerate.

The exposure of conglomerate in this area is less than 40 yards in width, and affords evidence of being a channel deposit. Although it occurs at the base of the Atoka formation, its channel filling nature prohibits one from considering it as definitely correlative with any of the designated marine members of the Atoka formation. Sandstones of the Georges Fork-Dirty Creek sequence directly overlie the conglomerate at this locality. Figs. 1 and 2 are photographs of the conglomerate approximately 150 yards north of the Wagoner Pumping Station, showing a portion of its thickness; Fig. 3 is a view of the contact with the underlying Morrow (Hale) limestone.

The Coody sandstone is conglomeratic locally, but in many areas it consists of buff to purplish quartz sandstones, leached and punky. In other areas the sandstones are friable and speckled with limonitic specks; some areas have firmly cemented and massive Coody sandstones; others exhibit thin-bedded, contorted, cross-bedded sandstones, high in iron oxide content.

Basal portions of the Coody member immediately above the contact with the underlying Morrow limestone are highly calcareous in many places

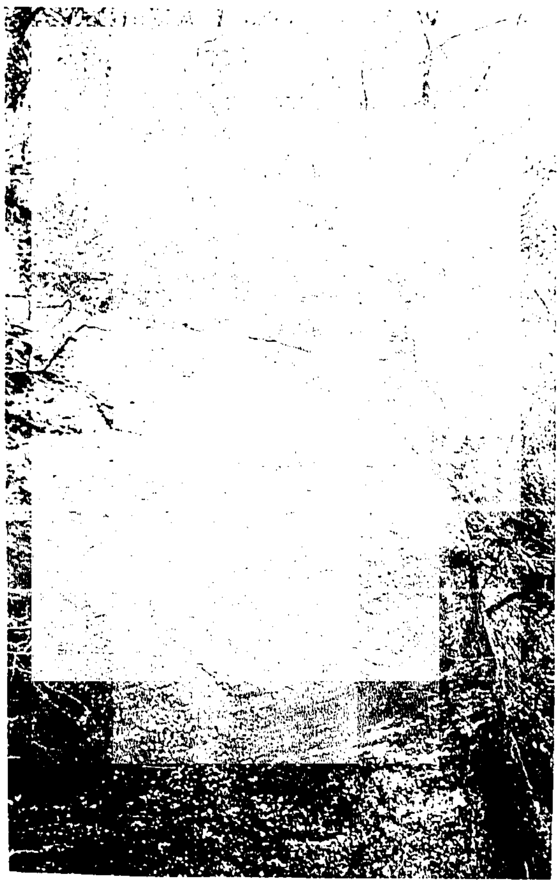


Fig. 1 -- Basal Atoka chert-pebble conglomerate, NW¼ sec. 20, T. 18 N., R. 19 E., on the western shore of Fort Gibson Lake, Wagoner County, Oklahoma. The full thickness of this conglomerate is approximately 15 feet.

and the zone is characterized by several inches to several feet of limestone pebble conglomerate and calcarenite. Figs. 4 and 5 are views of the Atoka-Morrow contact exposed in an inlier in Akins Hollow in the W½ sec. 4, T. 13 N., R. 25 E., in the Brushy Mountain area of Sequoyah County, Oklahoma. The inlier is a result of erosion on the upthrown, or south, side of the southeastward trending Greasy Creek fault. Fig. 6 shows this fault and the adjacent drag zone exposed in a cut of U. S. Highway 59 on the north flank of Brushy Mountain.

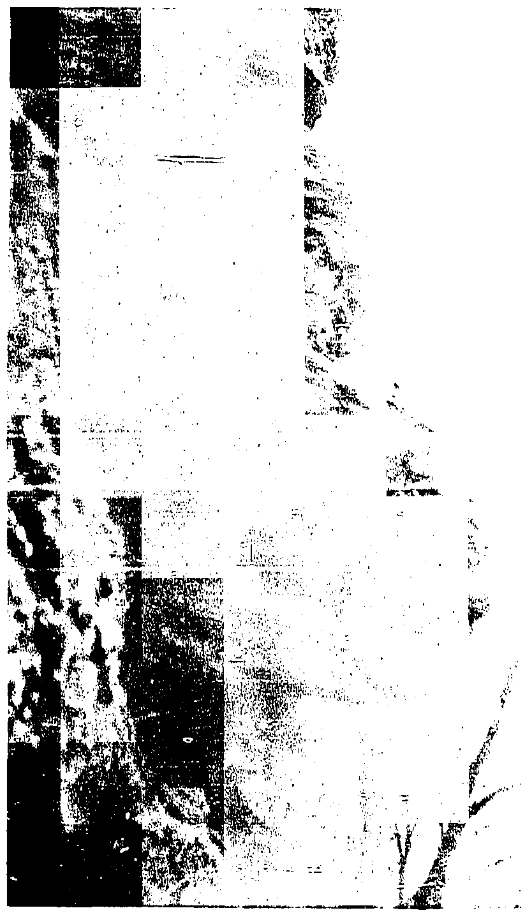


Fig. 2 -- Slump-block of basal Atoka chert-pebble conglomerate, NW¼ sec. 20, T. 18 N., R. 19 E., on the western shore of Fort Gibson Lake, Wagoner County, Oklahoma.

Punky, porous sandstones at higher levels in the Coody member have perhaps gained a measure of their porosity through leaching of calcium carbonate cement. A thick, massive, 50-foot section of sandstone in the Coody interval exposed in a cliff on the east wall of Akins Hollow in the SW¼ sec. 4, T. 13 N., R. 25 E., east of Brushy Mountain, in Sequoyah County, exhibits a honey-comb variety of weathering that is presumably due to leaching of more soluble carbonate components of the sandstone.

Fig. 3 -- View of the disconformable contact between the overlying Atoka channel conglomerate and the underlying Morrow (Hale) calcarenite, NW¼ sec. 20, T. 18 N., R. 19 E., on the western shore of Fort Gibson Lake, Wagoner County, Oklahoma. Hammer head is in contact with one of the ocherous clay pods which are abundant in the basal portion of the conglomerate; the end of the handle rests upon the Hale calcarenite.

Fig. 7 is a view of this sandstone exposed in the west wall of the valley.

Coody sandstones are characterized by abundant cross-bedding in many places. Fig. 8 is a view of a typical massive cross-bedded Coody sandstone in the NE¼ sec. 5, T. 13 N., R. 25 E., in Sequoyah County. Figs. 9 and 10 are exposures of cross-bedded sandstones of the sequence mapped as Coody-Pope Chapel in Wagoner and Mayes Counties.

Thin slabby sandstones in the Coody-Pope Chapel section approximately one mile north of Oklahoma Highway 51 on the west side of Fort Gibson Lake are characterized by high porosity and a dirty light grayish buff

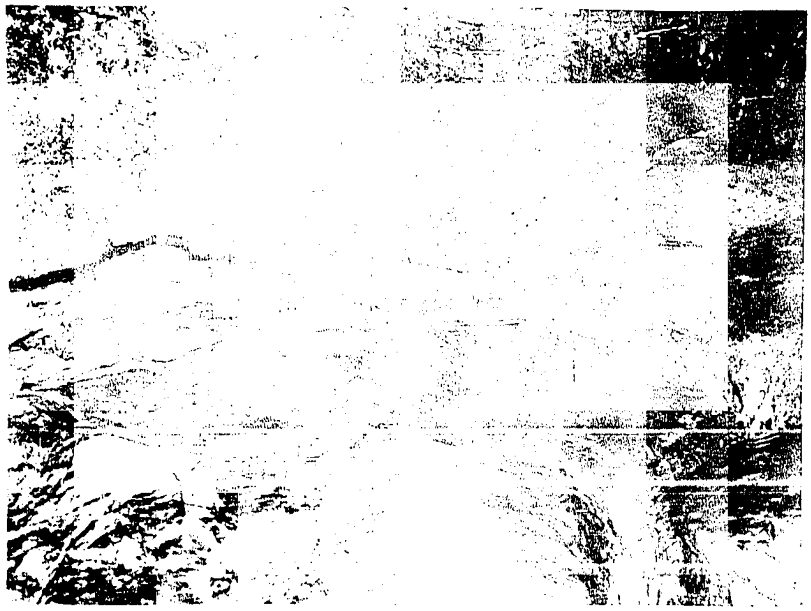


Fig. 4 -- View of the Atoka-Morrow contact as exposed in an inlier located in Akins Hollow, SW¼ sec. 4, T. 13 N., R. 25 E., Sequoyah County, Oklahoma. Hammer lies on Morrow limestone immediately beneath the level of the unconformity.

color, with many purplish specks representing small areas of iron oxide concentration. Fig. 11 exhibits a view of the contact of these sandstones with the underlying calcarenites of the Hale formation in this area.

In the Coody member, many of the coarser sandstones possess clear quartz grains which exhibit remnants of crystal faces.

Wilson (1935) identified the Timber Ridge sand of the subsurface of Muskogee County as equivalent to the Coody sandstone of the outcrop areas.

In Sequoyah County and other areas to the south and east of the Muskogee-Porum area, lower Atoka sandstones are much thicker than those in the Muskogee-Porum area, and constitute part of the McAlester Basin section. These sandstones, though in part equivalent to the Coody sand-

Fig. 5 -- View of the Atoka-Morrow contact exposed in an inlier in Akins Hollow, SW¼ sec. 4, T. 13 N., R. 25 E., Sequoyah County, Oklahoma. Hammer handle spans the contact; the base of the handle makes contact with the Atoka formation and the hammer head rests upon the Morrow limestone.

stone of the Muskogee-Porum area, are undoubtedly older than the Coody member in their lower portions. Hundreds of feet of Atoka sediments were deposited in the McAlester Basin before the sandstones of the Coody member were deposited on the shelf. This judgment is based primarily upon the fact that most of the Atoka sediments appear to have been deposited in very shallow water or, in some cases, subaerially, on broad swampy alluvial plains. If the basin sediments, deposited in such an environment, accumulated to much greater thicknesses than those of the shelf, it appears that the lower portions of the basinal sediments must have been deposited earlier than the shelf portions. Also, the prominent unconformity at the base of the Atoka formation on the shelf is apparent-

Fig. 6 -- Exposure of the Greasy Creek fault and the adjacent zone of drag in sandstones of the Coody member. Road cut of U. S. Highway 59, NW¼ sec. 5, T. 13 N., R. 25 E., Sequoyah County, Oklahoma. The left hand (south) side of the fault is the upthrown block.

ly missing, or very obscure, in the basin, indicating that deposition was occurring in the basin at the same time that erosion was progressing on the shelf. Upper units of the Atoka formation do not appear to exhibit the pronounced thickening basinward that is exhibited by the Coody-Pope Chapel sequence.

The Pope Chapel sandstone member was described by Wilson and Newell (1937, p. 28) as "characteristically a hard,calcareous, greenish-gray to buff sandstone. Locally it is cross-bedded and rarely it contains molds of pelecypods and Spirifer occidentalis. It ranges in thickness from 10 to 20 feet."

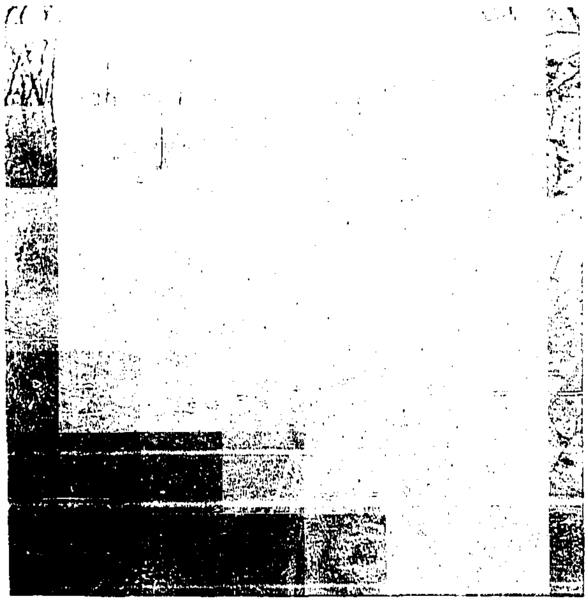


Fig. 7 -- 50-foot cliff of massive Coody sandstone exposed on eastern wall of deep valley of Akins Hollow in SW¼ sec. 4, T. 13 N., R. 25 E., Sequoyah County, Oklahoma.

Fig. 8 -- Massive, cross-bedded Coody sandstone in the NE¼ sec. 5, T. 13 N., R. 25 E., Sequoyah County, Oklahoma.

Fig. 9 -- Cross-bedded sandstone of the Coody-Pope Chapel sequence, Poindexter Ferry area, NW¼ sec. 29, T. 18 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 10 -- Cross-bedded sandstone of the Coody-Pope Chapel sequence, NW¼ sec. 17, T. 18 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 11 -- Contact of Atoka sandstone of the Coody-Pope Chapel sequence with the underlying calcarenites of the Hale formation. Hammer located at contact. Note cross-bedding in the Hale formation. SW¼ sec. 15, T. 17 N., R. 19 E., Wagoner County, Oklahoma.

Along the west line of sec. 24, T. 12 N., R. 19 E., in Muskogee County, the Pope Chapel is typically coarse-grained buff to brown to greenish-gray sandstone. The grains are subangular to subrounded and some are frosted. A limonitic cement is abundant, and some limonitic boxlike concretionary structures are present. In the NE¼ sec. 12, T. 12 N., R. 19 E., the Pope Chapel sandstone is well cemented and massive, white to tan, and characteristically coated with lichens. In the SE¼ sec. 34, T. 15 N., R. 19 E., the Pope Chapel is a medium-grained buff porous sandstone with iron oxide and clay cementing materials. The grains are clear, and the rock weathers dirty pinkish-gray to pinkish-brown. The quartz grains in this rock range from approximately 0.1 to 0.25 mm in diameter, and are subangular. Many of the grains are clear with few inclusions, but other areas of the rock are characterized by quartz grains with many inclusions. Many of the sandstones of the Pope Chapel member are friable. A typical exposure of Pope Chapel sandstone is shown in Fig. 12.

Fig. 12 -- Pope Chapel sandstone near C.W.L. sec. 19, T. 12 N., R. 20 E., in Muskogee County, Oklahoma.

A quarry in the SW¼ sec. 12, T. 18 N., R. 18 E., in Wagoner County exposes the Lower Atoka Coody-Pope Chapel sandstones. The sandstones in this quarry are buff, speckled with limonitic specks, massive, somewhat friable, and characterized by normal cross-bedding in certain portions of the section. The sandstones are reminiscent of the typical Pope Chapel sandstone of the Muskogee-Porum area. Fig. 13 shows these sandstones well displayed in the quarry walls.

A general characterization of the Coody-Pope Chapel sequence as mapped in Wagoner and Mayes Counties is as follows: sandstones of the upper part are massive, medium-grained, locally cross-bedded, composed

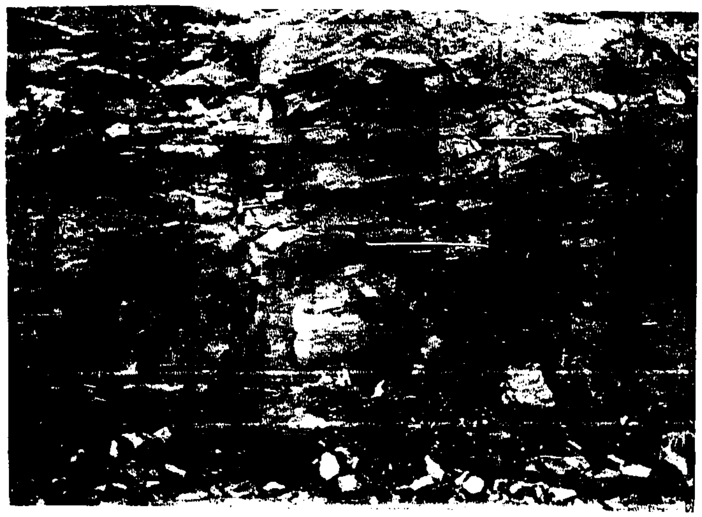


Fig. 13 -- Coody-Pope Chapel sandstone. Quarry in SW¼ SW¼ sec. 12, T. 18 N., R. 18 E., Wagoner County, Oklahoma.

of rounded and frosted quartz grains; sandstones of the lower part are thin-bedded to massive, locally cross-bedded, porous, possessing a dull luster and many characterized by brownish to purplish specks. Basal beds are locally conglomeratic with chert pebble and ferruginous limestone pebble conglomerate in zones of various thicknesses above the major unconformity at the base of the Atoka.

Much thicker sections of Pope Chapel equivalents are present in the McAlester Basin sections south and east of the Muskogee-Porum area.

The Coody-Pope Chapel sequence has not been recognized north of Township 20 N. The northernmost location at which Coody-Pope Chapel facies has been confidently recognized is the NE¼ NE¼ sec. 16, T. 20 N., R. 18 E., although the basal few feet of Atoka sandstone in a small localized area of the Seneca graben in SW¼ SW¼ sec. 15, T. 22 N., R. 20 E., resembles the Pope Chapel facies. Fig. 14 is a photograph of these sandstones, exhibiting steep dips characteristic of the zone of drag of the northern fault of the Seneca graben in this area.

In the southern portion of the Oklahoma Ordnance Works area in Township 20 N., the Coody-Pope Chapel facies apparently thins to extinction, being overlapped in this area by the Georges Fork-Dirty Creek sequence.

The two units immediately overlying the Pope Chapel sandstone in the Muskogee-Porum area are the Georges Fork and Dirty Creek sandstones, respectively. These units are not differentiated in Wagoner and Mayes

Fig. 14 -- Lower Atoka sandstone resembling the Pope Chapel facies. Steep dip due to drag near northern fault of the Seneca graben. SW¼ SW¼ sec. 15, T. 22 N., R. 20 E., Mayes County, Oklahoma.

Counties, but are mapped as a single unit.

The Georges Fork sandstone of the Muskogee-Porum area was described by Wilson and Newell (1937, p. 29) as "a hard calcareous greenish-gray to black, unfossiliferous sandstone, having a thickness of 3 to 5 feet. A maximum thickness of 15 feet was measured in sec. 7, T. 14 N., R. 20 E., on the east bluff of Arkansas River..."

In the northeast corner of sec. 2, T. 14 N., R. 19 E., the Georges Fork is a fine-grained, slightly micaceous, olive-buff to dark olive green sandstone with irregular streaks of buff. The rock weather light olive-buff to dark dirty gray.

In general, the Georges Fork sandstone is of finer grain and darker color than the Coody-Pope Chapel sandstones and constitutes a thinner and perhaps less persistent unit.

The Dirty Creek sandstone member, in the Muskogee-Porum area, is a black to greenish-buff sandstone with Taonurus markings, and is approximately 15 feet thick (ibid., pp. 29-30). In other portions of the area it is a 3- to 8-foot sandstone, buff, calcareous, and unfossiliferous (ibid., p. 30).

Samples of Dirty Creek sandstone collected during the present study from the NW¼ sec. 3, T. 14 N., R. 19 E., are fine-grained, olive buff sandstones, with quartz cement. They weather orange buff to dirty grayish brown. Other specimens are dark olive green to olive brown, with reddish-brown to dark maroon splotches of ocherous hematitic clay or clay cement. Others are buff, medium-grained, and porous, with iron oxide-coated pore spaces. The weathered surfaces of Dirty Creek sandstones appear case-hardened and quartzitic on many areas of outcrop.

In Wagoner and Mayes Counties, the Georges Fork-Dirty Creek sequence may contain equivalents of either or both units as distinguished in the Muskogee-Porum area. The sequence may be characterized as fine-to medium-grained sandstone, in part firmly cemented and quartzitic in appearance, and in part loosely cemented and friable. Colors range from pinkish-white through reddish-brown to dark olive green and olive brown. Fucoid-like markings and Taonurus are locally abundant. Chert pebble conglomerates are locally present near the base, especially in those areas where the Georges Fork-Dirty Creek sequence overlaps the underlying Coody-Pope Chapel sequence northward upon older rocks.

The Georges Fork-Dirty sequence has been mapped locally into Township 22 N. where the northernmost exposure is in the Seneca graben. In general, the Blackjack School sandstone member overlaps the Georges Fork-Dirty Creek sequence in Township 21 N., approximately one mile south of Pryor.

In certain areas, such as the southern portion of the grounds of the Pryor Ordnance Works, the Coody-Pope Chapel sequence and Georges Fork-Dirty Creek sequence appear to merge so intimately as to be indistinguishable on the outcrop. In this area, the Atoka sandstones are mapped as "Lower and Middle Atoka Undifferentiated." This area represents essentially the latitude of Georges Fork-Dirty Creek overlap of the Coody-Pope Chapel sequence. As the underlying Coody-Pope Chapel section thins to extinction and the overlying shale thins drastically, a merging of the lower and middle Atoka sandstones is effected.

In the N½ sec. 4, T. 20 N., R. 19 E. an excellent conglomeratic phase of the Georges Fork Dirty-Creek succession is exposed in a cut of the railroad spur in the Pryor Ordnance Plant grounds. This conglomerate contains rounded chert pebbles and limestone pebbles, firmly cemented by an iron oxide, manganese oxide, siliceous and clay cement. In this cut the conglomerate lies directly upon the Fayetteville formation, having been deposited in depressions cut into the Fayetteville formation to depths of 20 feet or more. The conglomerate contains some limestone pebbles derived from the underlying Fayetteville formation.

The Webbers Falls member is the most distinctive member of the Atoka formation in northeastern Oklahoma. Wilson and Newell (1937, p. 30) describe the member as a siltstone,

> dark green to black where unweathered, changing to gray or grayish-buff on exposure. Generally the individual layers are relatively thin and weather into small angular fragments and blocks which have a striking resemblance to deeply weathered chert. In fact such fragments are highly siliceous. The fresh rock also appears siliceous, but to a lesser degree, and is commonly so highly calcareous and carbonaceous that it might well be termed a carbonaceous, silty limestone. In the more calcareous phases, poorly preserved marine fossils: crinoid stems, brachiopods and pelecypods are relatively common.

The Webbers Falls member, though distinctive, consists of varying characteristic lithologies in Wagoner and Mayes Counties. The description presented by Wilson and Newell applies to many exposures. Siltstones, with a range in color from light buff to dark gray, range from highly vesicular to dense and cherty. Fig. 15 is a photograph of a typical exposure of Webbers Falls siltstone in the NW¼ sec. 26, T. 12 N., R. 19 E., in Muskogee County. Typical exposures of the vesicular phase of the member are shown in Figs. 16 and 17. The vesicular varieties at places contain zones with irregular cores of medium crystalline limestone. Fig. 18 is a photograph of vesicular Webbers Falls siltstone and associated interpenetrating core limestone. The picture is partially illustrative of the intimate manner in which the siltstone envelops the

Fig. 15 -- Webbers Falls siltstone in NW¼ sec. 26, T. 12 N., R. 19 E., in Muskogee County, Oklahoma. The zone at the level of the hammer shows the characteristic shattered appearance of the immediate subsoil portions of the member, and the zone beneath the hammer exhibits the characteristic "fracture-like" bedding.

limestone and the limestone interpenetrates the siltstone. Figs. 19 and 20 also exhibit typical relationships displayed by the vesicular siltstone of the Webbers Falls member and its intimately interpenetrating core limestone. Calcarenites are locally conspicuous in the Webbers Falls member and at places grade laterally into the core limestone and vesicular siltstone portions of the member. Figs. 21, 22, and 23 are photographs of typical Webbers Falls calcarenites. Siltstones and silty carbonaceous limestones of the member typically exhibit excellent jointing, with the outcrops resembling a heavy pavement of quarried, sawed, and fitted blocks. Fig. 24 is a view looking down upon an outcrop of Webbers Falls member in the Verdigris River at Okay, Oklahoma, from a bridge

Fig. 16 -- Vesicular Webbers Falls siltstone, exhibiting characteristic "termite-riddled" appearance. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water near the eastern shore of Fort Gibson Lake.

approximately 25 feet above the outcrop. Certain thin portions of the Webbers Falls member are cherts. Approximately one mile east of Wagoner on the road to Wagoner City Park, a thin 6-inch zone of light greenish-gray chert in the Webbers Falls member is exposed. This chert is associated with a typical vesicular Webbers Falls siltstone, riddled with holes approximately 0.75 to 1.0 inch in diameter. Figs. 25 and 26 illustrate the lithology at this location. In thin section, the chert is found to consist of matted and "woven" spicules in great abundance, as shown in Fig. 52.

The Webbers Falls siltstones are prominently exposed immediately south of the bridge over the Verdigris River at Okay in Wagoner County, as well as in the cliffs on the east side of the river approximately one

Fig. 17 -- Vesicular Webbers Falls siltstone with "termite-riddled" appearance. NE¼ sec. 27, T. 17 N., R. 19 E., Cherokee County, Oklahoma, along abandoned portion of old Oklahoma State Highway 51, approximately 60 yards south of the present highway. Hammer rests on a cross-bedded calcarenite portion of the Webbers Falls member.

mile south of Okay. Fig. 27 is a photograph showing the northward-dipping Webbers Falls siltstones which form a riffle in the Verdigris River. A measured section of the Webbers Falls in the cliffs south of Okay is included in the appendix of this report. Fig. 28 is a photograph of a portion of this section. The siltstones exposed immediately south of the bridge at Okay are dark gray to black, massive, and exhibit the characteristic rectangular jointing mentioned above. (See Figs. 24 and 27.) Impressions of coiled cephalopods and pectinoid pelecypods are fairly abundant, as are peculiar sinuous carbonaceous "worm" markings. Shales beneath the siltstones yield flattened and, in some specimens, pyritized

Fig. 18 -- Vesicular Webbers Falls siltstone and core limestone. Siltstone is at the level of the hammer head; core limestone is at the level of the hammer handle. Picture is partially illustrative of the intimate manner in which the siltstone envelops the limestone and the limestone interpenetrates the siltstone. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water near the eastern shore of Fort Gibson Lake.

gastropods, while thin ferruginous limestones in the shales above the Webbers Falls yield brachiopods such as Spirifer occidentalis, Neospirifer cameratus, Marginifera cf. muricatina, as well as crinoid stem ossicles, gastropods, and Bryozoa.

Pectinoid pelecypod impressions are found in the Webbers Falls siltstones southeast of Wagoner on Oklahoma State Highway 51 and in other areas.

An excellent Atoka fossil locality is in the dark gray shales beneath the Webbers Falls siltstones in the road cut at the east end of

Fig. 19 -- Vesicular siltstone and interpenetrating core limestone of the Webbers Falls member. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake, near the eastern shore.

Fig. 20 -- Vesicular siltstone and interpenetrating core limestone of the Webbers Falls member. Hammer head rests mainly on the limestone core but the tip rests on the siltstone. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma

Fig. 21 -- Calcarenite, or clastic limestone, portion of the Webbers Falls member near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake, near the eastern shore.

Fig. 22 -- Webbers Falls calcarenite grading upward into siltstone at position of tip of hammer handle. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake, near the eastern shore.

Fig. 23 -- Calcarenite portion of Webbers Falls member. Note small thrust fault or slumpage surface along line indicated by pencil. Shale chips are included in the calcarenite. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake.

Fig. 24 -- View looking down upon strongly jointed Webbers Falls calcareous siltstone exposed in the bed of the Verdigris River at Okay, Wagoner County, Oklahoma. NE¼ SE¼ sec. 19, T. 16 N., R. 19 E.

Fig. 25 -- Blocks of vesicular Webbers Falls siltstone and associated thin chert. SE¼ sec. 7, T. 17 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 26 -- Blocks of vesicular Webbers Falls siltstone and associated thin chert layer. Extended knife blade points to thin chert layer. SE¼ sec. 7, T. 17 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 27 -- Northward-dipping Webbers Falls siltstones in the bed and eastern bank of the Verdigris River at Okay, Oklahoma. The dip is believed to be due to drag along a fault which crosses the river immediately to the left of this view. Note strong regular jointing, characteristic of Webbers Falls siltstones. NE¼ SE¼ sec. 19, T. 16 N., R. 19 E., Wagoner County, Oklahoma.

the Oklahoma State Highway 51 bridge over Fort Gibson Lake, approximately 8 miles east of Wagoner. The fossiliferous shales at this locality are shown in Fig. 29, and the faunule collected from this locality is described in Chapter V of this report.

Some of the gray shales of the Webbers Falls member contain multitudinous nodules of dark gray lithographic limestone, which weather a light cream color upon exposure. Fig. 30 is a photograph of a characteristic exposure of this lithology.

Figs. 31, 32, 33, 34, 35, 36, and 37 are additional photographs of Webbers Falls lithologies.

Fig. 28 -- Limestones and siltstones of the Webbers Falls member exposed in the eastern bluffs of the valley of the Verdigris River about one mile south of Okay, Oklahoma. SW¼ sec. 29, T. 16 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 29 -- Fossiliferous Atoka shale beneath the Webbers Falls siltstones in a road cut of Oklahoma State Highway 51 at the eastern end of the bridge over Fort Gibson Lake. Near northeast corner sec. 27, T. 17 N., R. 19 E., Cherokee County, Oklahoma.

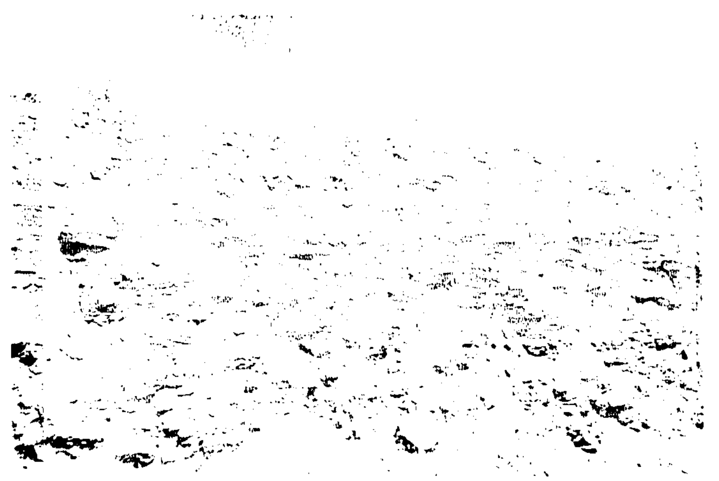


Fig. 30 -- Webbers Falls shales and nodular limestones exposed in railroad cut near southwest corner sec. 6, T. 18 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 31 -- Webbers Falls siltstones, limestones, and shales at Hulbert Landing, SW¼ sec. 21, T. 17 N., R. 20 E., Cherokee County, Oklahoma.

Fig. 32 -- Webbers Falls siltstones, thin limestones, and shales at Hulbert Landing, SW¼ sec. 21, T. 17 N., R. 20 E., Cherokee County, Oklahoma.

Fig. 33 -- Webbers Falls vesicular siltstone and core limestone. Pencil points to a localized center of limestone. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake.

Fig. 34 -- Webbers Falls calcarenite. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake.

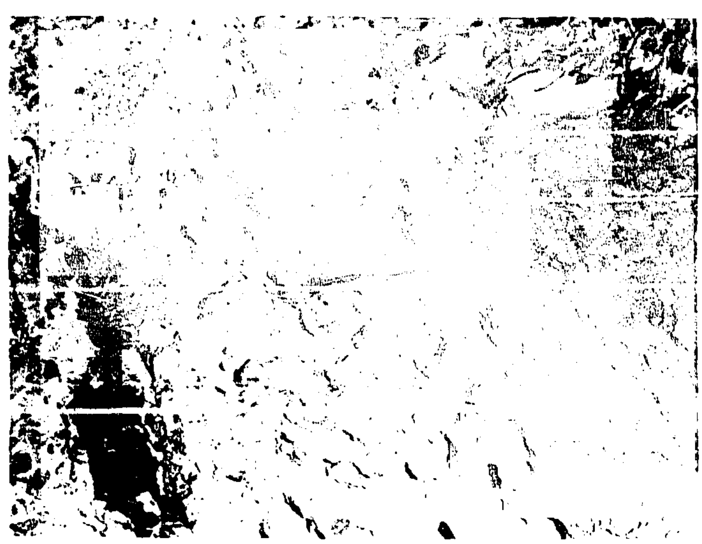


Fig. 35 -- Webbers Falls vesicular siltstone and core limestone. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake.

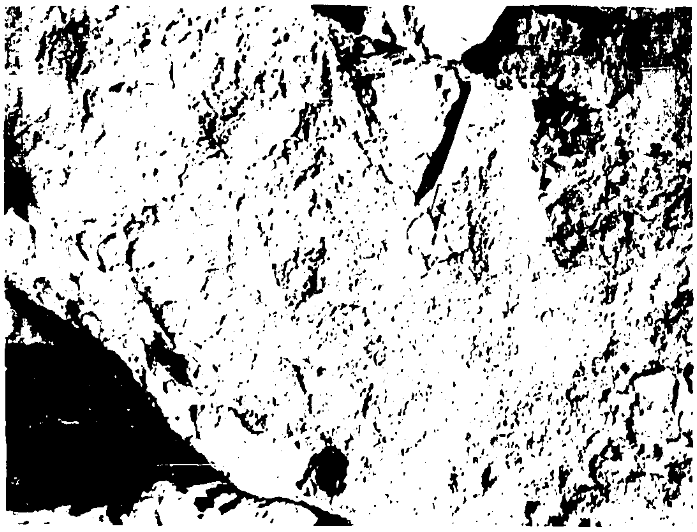


Fig. 36 -- Webbers Falls calcarenite with contained chips and flakes of shale. Pencil points to a shale chip. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake.

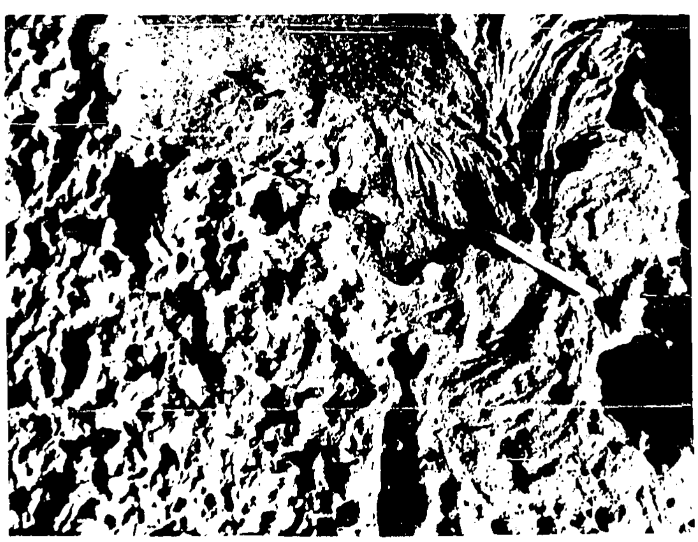


Fig. 37 -- Taonurus marking in vesicular Webbers Falls siltstone. Near C.N.L. sec. 34, T. 16 N., R. 19 E., Cherokee County, Oklahoma. This former exposure is now beneath the water of Fort Gibson Lake.

Webbers Falls siltstones form small escarpments in some areas, but the limestones and shales are characteristically found in stream beds or underlying subdued slopes.

The Webbers Falls member has been traced in the present study to the area north of Chouteau in Mayes County, where a prominent exposure along Chouteau Creek in sec. 24, T. 20 N., R. 18 E., represents the northernmost exposure of definitely recognized Webbers Falls. In this area the Webbers Falls thins to extinction, or loses identity as a result of a facies change to a dominantly shale section, between the Blackjack School member and the underlying Georges Fork-Dirty Creek sequence, which has been traced a few miles farther north to the latitude of Pryor.

The limestones in the Webbers Falls and overlying Blackjack School member are believed to constitute the "lime marker" or "Muskogee lime" in the subsurface of Muskogee County. This datum bed lies immediately above the Dutcher sands of the middle and lower portions of the Atoka formation.

The Blackjack School sandstone member, according to Wilson and Newell (1937, p. 33), is named for Blackjack School in sec. 9, T. 11 N., R. 19 E., and consists of two prominent thin-bedded sandstone sections separated by 15 feet of shale at the type locality. A portion of the upper section at the type locality is illustrated in Fig. 38. Wilson and Newell (ibid.) also stated that:

> the Blackjack School succession consists of three to four erratic buff or greenish sandstones separated by dark gray silty shale, measuring in aggregate from 60 to 85 feet. The individual sandstones are commonly no more than 2 feet thick, but range up to a maximum of about 10 feet.

In Wagoner and Mayes Counties, the Blackjack School sandstones

Fig. 38 -- Thin-bedded Blackjack School sandstones at the type locality near Blackjack School, southeast corner sec. 5, T. 11 N., R. 19 E., Muskogee County, Oklahoma.

are characteristically buff to rusty brown, micaceous, and locally characterized by scattered limonitic specks. Typically these sandstones are less micaceous and darker than the overlying Warner sandstone. Many Blackjack School sandstones are thin-bedded and are characterized by abundant ripple marks. Figs. 39, 40, and 41 are photographs of different exposures of the Blackjack School member.

The shale zone above the Blackjack School probably contains locally thin Hartshorne sandstone and siltstone. Areas mapped as Atoka formation in northern Mayes County may be Hartshorne sandstone, entirely or in part.

The Blackjack School sandstones are characterized, in places, by the "rooster-tail" markings, <u>Taonurus</u>, although these markings do not appear to be as abundantly represented in the Blackjack School sandstone

Fig. 39 -- Blackjack School sandstones exposed on the eastern bank of the Verdigris River at Okay, Oklahoma. SW¼ sec. 19, T. 16 N., R. 19 E., Wagoner County, Oklahoma.

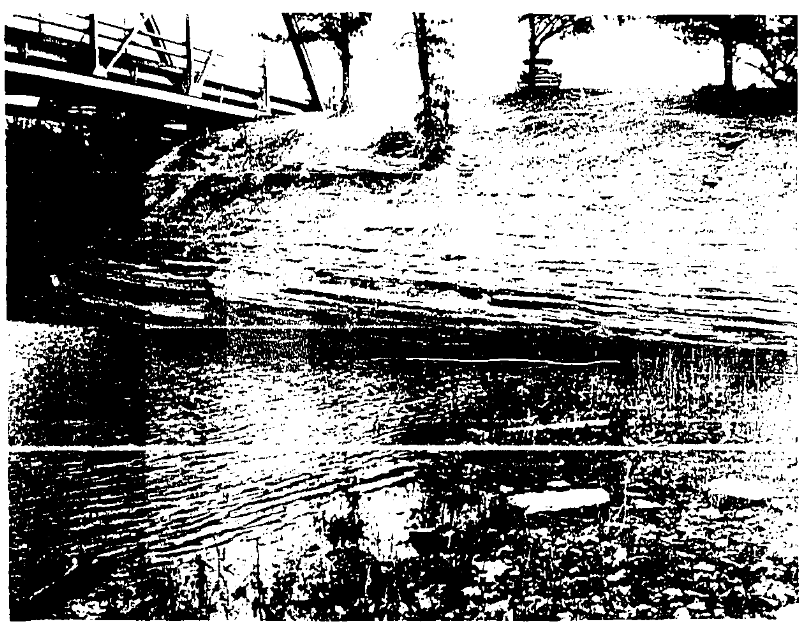


Fig. 40 -- Blackjack School sandstones exposed on the eastern bank of Fourteen Mile Creek, SE¼ sec. 21, T. 17 N., R. 20 E., Cherokee County, Oklahoma. These sandstones are thin-bedded and ripple-marked.

Fig. 41 -- Thin-bedded Blackjack School sandstones and shales cut by small fault at position of hammer. SE¼ sec. 30, T. 18 N., R. 19 E., Wagoner County, Oklahoma.

as they are in the sandstones of the Georges Fork-Dirty Creek sequence.

Thin, highly fossiliferous, ferruginous limestones and gray to buff cross-bedded calcarenites occur locally. Figs. 42, 43, and 44 illustrate Blackjack School limestones in railroad cuts in northern Wagoner County.

Many of the Blackjack School limestones qualify as typical organic limestones, filled with organic debris, including echinoderm fragments, bryozoan remains, fusulinids, and brachiopods. Photographs of thin sections of Blackjack School limestones constitute Figs. 59, 60, and 61.

The Blackjack School member overlaps all older Atoka members northward, and has been traced to the general area of its extinction a few miles north of Adair in northern Mayes County.

Stream channel deposits of Atokan age are present in isolated small areas in Craig County north of Grand Lake and south of United States

Fig. 42 -- Light gray, fossiliferous, Blackjack School limestone and calcarenite and underlying shales. SW¼ sec. 13, T. 18 N., R. 18 E., Wagoner County, Oklahoma.

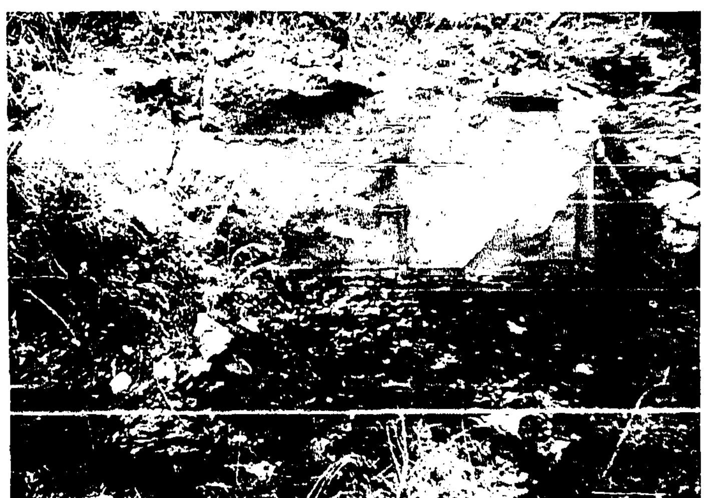


Fig. 43 -- Light gray, fossiliferous, Blackjack School limestone and calcarenite and underlying shales. SW¼ sec. 13, T. 18 N., R. 18 E., Wagoner County, Oklahoma.

Fig. 44 -- Highly ferruginous Blackjack School limestone near center sec. 13,T. 18 N., R. 18 E., Wagoner County, Oklahoma.

Highway 66. These exhibit prominent scour and fill characteristics and are typically dark gray to black due to small amounts of interstitial asphaltic material. Fig. 45 is a photograph of one of these channels.

The northernmost outcrop of sandstones presumed to belong to the Atoka formation occurs about 5 miles east of Vinita and ½ mile north of United States Highway 66 in sections 21 and 22 of T. 25 N., R. 21 E., in Craig County. The sandstone is conglomeratic, and caps a small hill at this location. Fig. 46 shows a specimen of this conglomeratic sandstone containing flattened pebbles of lithographic limestone derived from the underlying Fayetteville formation.

Befitting its overlapping characteristics, the Blackjack School member is conglomeratic near its base in certain areas. In the SE¼ sec. 30, T. 18 N., R. 19 E., the Blackjack School member locally contains

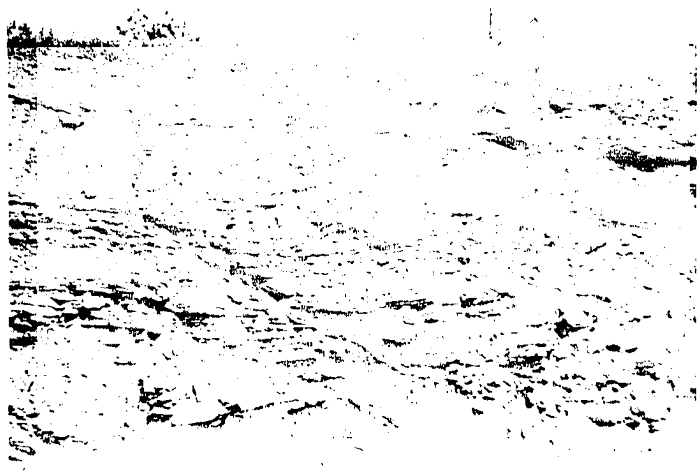


Fig. 45 -- Atoka channel sandstones showing scour and fill structure. SW¼ sec. 3, T. 24 N., R. 21 E., Craig County, Oklahoma.

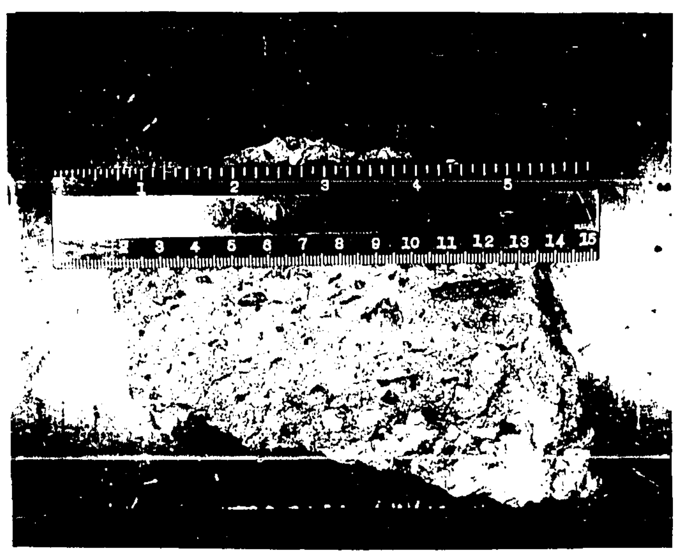


Fig. 46 -- Conglomeratic sandstone, presumably belonging to the Atoka formation, containing flattened pebbles of lithographic limestone derived from the underlying Fayetteville formation. Near C.E.L. sec. 21, T. 25 N., R. 21 E., Craig County, Oklahoma.

chert pebbles attaining 3 inches in diameter. Fig. 47 shows a specimen of this conglomerate. Conglomeratic Blackjack School sandstone is also well exposed along the north line of the NE¼ sec. 12, T. 17 N., R. 18 E., approximately one mile east of Wagoner. In this area, the shale interval between the Blackjack School sandstone and the underlying Webbers Falls siltstone is only 5 feet. This fact suggested to Wilson and Newell (1937, p. 31) that the Webbers Falls member was cut out by overlap a short distance northeast of Wagoner, but the present study has served to convince the writer that such is not the case except in possible local instances, inasmuch as the Webbers Falls member has been traced to an area north of Chouteau in Mayes County during the present investigation.

Another area of conglomeratic Blackjack School sandstone is in NW ¼ sec. 5, T. 18 N., R. 19 E., and SW¼ sec. 32, T. 19 N., R. 19 E. on the Wagoner-Mayes County line. This small area of exposure is on a hill crest, and the Blackjack School is here separated from the Webbers Falls by approximately 4 feet of shale.

The Blackjack School sandstone member normally forms the remnant caps of high hills near Grand River or forms subdued escarpments at one or more levels below the Warner escarpment.

The Blackjack School sandstone is sparsely fossiliferous, but contains occasional molds of the brachiopods Spirifer occidentalis, Punctospirifer, and Mesolobus mesolobus. The limestone members at many places contain broken shells of Neospirifer cameratus in considerable abundance, as well as crinoid ossicles, and other fragmentary fossils.

The stratigraphic position of the Blackjack School sandstone below the readily traceable Warner escarpment and above the distinctive, though in many places concealed, Webbers Falls member, serves to identify the Blackjack School interval with a certainty that would not always be possible otherwise.

The basal units of the Atoka formation rest upon rocks of Morrowan age in Wagoner County and most areas of Mayes County south of the general latitude of Chouteau. In the general latitude of Pryor, the Morrowan strata thin to extinction, and the Atoka formation rests upon the Fayetteville formation of Upper Mississippian (Chester) age. In local areas south of Pryor, Atoka strata directly overlie the Fayetteville formation, as in sections 8 and 16 of T. 19 N., R. 19 E., approximately 3 miles southeast of Chouteau in southern Mayes County, in the cuts of the railroad spur leading to the Pryor Ordnance Works in sections 4 and 5 of T. 20 N., R. 19 E., approximately 3½ miles south of Pryor, and other areas immediately south of Pryor in sections 28 and 29 of T. 21 N., R. 19 E.

A highly fossiliferous fragmental limestone pebble conglomerate zone in the basal portion of the Blackjack School member southeast of Adair (sec. 2, T. 22 N., R. 19 E. and sec. 35, T. 23 N., R. 19 E.) rests upon the underlying Fayetteville formation in typical unconformable relationship.

In summary, the Atoka formation thins northward from the Muskogee-Porum area, where its thickness is approximately 600 feet, to its feather edges in the latitude of extinction in northern Mayes and southeastern Craig Counties. In this area, on the north side of the McAlester Basin and the west flank of the Ozark Uplift, it may be characterized as a shelf facies, with lithologic characteristics modified by the tectonic

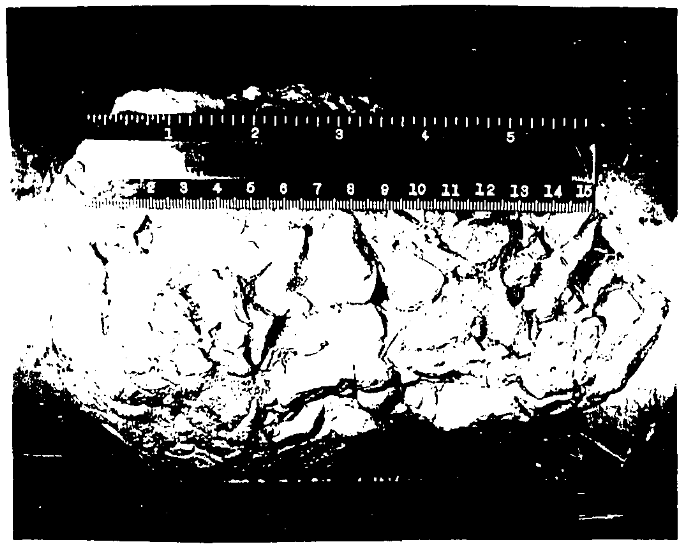


Fig. 47 -- Specimen of Blackjack School conglomerate which caps a small ridge in SE¼ sec. 30, T. 18 N., R. 19 E., Wagoner County, Oklahoma.

influences of the subsiding basin to the south, the gently positive area to the east, and the relatively stable,though somewhat oscillatory cratonal area to the north and northwest. With source areas in the island arc area in the Ouachita geosyncline to the south, or quite possibly in the newly uplifted folds of the Ouachita Mountains, the Ozark region to the east, and in the cratonal area to the north and northwest, the Atoka formation exists as a lithologic complex, modified by varying conditions of provenance and varying degrees and types of tectonic behavior.

A partial recognition of the influences of these differing factors on the lithology and stratigraphy of the formation is thought possible and will be attempted, in part, in the following pages. It is believed that this study will perhaps serve to provoke more questions than it answers, and may constitute a challenge to others who may desire to apply refined petrographic techniques in attempts to shed more light on a fascinating petrographic and stratigraphic enigma.

CHAPTER III

SEDIMENTATIONAL ASPECTS AND ENVIRONMENTS OF DEPOSITION

The Atoka sediments which accumulated on the northern shelf of the McAlester Basin presumably were derived from three different source areas: the newly uplifted Ouachita Mountains to the south, the area of the Ozark Uplift to the east and northeast, and the cratonal region bordering the Atokan sea on the north and northwest.

The thick basinal section of Atoka sediments appears definitely to have been derived from southern highlands in the general area of the Ouachita Mountains. Atokan rocks are thicker to the south in the McAlester Basin, indicating a primary source of sediments in the uplands to the south. The McAlester Basin apparently resulted in early Middle Pennsylvanian time from a northward shifting of the axis of maximum deposition from its original position in the Ouachita geosyncline, which had been located farther to the south in southeastern Oklahoma, southern Arkansas, northeastern Texas and northern Louisiana. The subsiding McAlester Basin was apparently choked by the rapid influx of sediment from the south, inasmuch as most of the thick Atokan section affords evidence of having accumulated in very shallow water. It seems likely that somewhat deeper (though shallow) marine waters covered the shelf area to the north than were present in the basin area proper.

Some of the sediment derived from the southern highlands undoubtedly contributed in a measure to the Atokan section of the shelf area on the north side of the basin, especially during times of exceptionally rapid sediment influx from the south. During such times, sediments were transported across a vast, slightly emergent, alluvial plain to a marine site of deposition on the northern margins of the basin. In general, deeper waters were present over the shelf areas than in the basinal areas (Branson, 1954, p. 1). Thick lower Atoka sections in Sequoyah County and southern Muskogee and Cherokee Counties presumably represent sediment contributions from a southern source.

Much of the thinner portions of the shelf section of the Atoka formation represents sediments derived from the Ozark Uplift to the east and the cratonal shores to the north. The general trend of the Atoka channel deposits in Craig County appears to indicate a northern, northeastern, or northwestern source. The chert pebble conglomerates present in various portions of the shelf section suggest a time of lower Middle Pennsylvanian erosion of areas of "Boone" or Keokuk chert in the Ozark Uplift to the east or, perhaps, the Bourbon Arch to the north.

Much of the cross-bedding in the typical Pope Chapel facies of the Atoka formation exposed in the quarry in SW¼ SW¼ sec. 12, T. 18 N., R. 18 E., is inclined toward the southeast, which fact, though not conclusive, does not militate against a northern or northwestern source.

As mentioned in Chapter I, the mapping of sand-shale ratios of Atoka sediments in the subsurface indicates an increase in sand-shale ratio northwestward in that area, with the clear implication that the sediments were derived from the cratonal areas to the north. Scruton

(1950, p. 423) stated that the thinning of the shelf section of the Atoka formation is accomplished primarily by thinning of the shale units. He referred to an increase in the sand-shale ratio from 1:7 in T. 12 N. to 1:1 in T. 16 N. This serves to indicate the importance of northern source areas for the Atoka sediments of the northeastern Oklahoma shelf.

The basal Coody-Pope Chapel sandstones of the Atoka formation are mapped as a unit in the Wagoner-Mayes County portion of the shelf area. This succession gives evidence of having been deposited under somewhat similar conditions of depositional environment and prevailing tectonism.

Petrographic analyses of selected sandstones of the Coody-Pope Chapel sequence reveal that these sandstones typically combine the characteristics of a subgraywacke and a quartzose sandstone. The quartz grains are in most cases not well rounded, ranging between subangular and subrounded, and the size ranges from approximately 0.5 mm to 0.062 mm in diameter. Their sorting is only fair to moderate. Small amounts of iron oxide and clay cementing materials are present, and the heavy mineral component appears to consist predominantly of the stable mineral zircon. In general, it may be said that the Coody sandstones are more typically subgraywackes, which accumulated on an unstable shelf, whereas the Pope Chapel sandstones exhibit more of the characteristics of a stable shelf environment. The somewhat "cleaner" quartzose sandstones of the Pope Chapel testify to a somewhat greater degree of winnowing action by waves and currents during the slow subsidence of a fairly stable shelf environment, whereas the earlier Coody sandstones bespeak of somewhat more unstable conditions, which permitted the subsidence of sediments below effective wave base before wave and current winnowing could adequately begin the removal of the clay and silt elements of the present matrix. Fig. 48 is a photograph of a thin section of Pope Chapel sandstone, showing the rather angular quartz particles, most of which contain inclusions, the finer grained matrix of quartz grains, and the iron oxide cement. Although neither the Coody nor Pope Chapel sandstones are typical stable shelf quartzose sandstones or typical unstable shelf subgraywacke sandstones, the Pope Chapel apparently represents conditions of comparatively greater shelf stability and somewhat shallower depositional sites. The presence of frosted sand grains in some Pope Chapel sandstones, the abundance of woody fragments, and the common friable nature of the rock, all suggest relatively shallow water environments.

The previous discussion relates directly to the Coody-Pope Chapel succession in the Wagoner-Mayes Counties area. In the basinal area to the south and southeast, lower Atoka sandstones are definitely subgraywacke types and witness to a depositional realm of unstable shelf and basinal areas. Whereas in the Wagoner-Mayes Counties area, the Coody-Pope Chapel sequence was deposited in the unda environment of Rich (1951, pp. 4-6), the same sequence of southern Cherokee County, Sequoyah County, and other areas farther south in the McAlester Basin, was deposited in the clino environment of Rich (1951, pp. 6-9). In the basinal areas, Atoka sandstones exhibit prominent features, such as flute markings, flow markings, and slump markings, characteristic of deposition on the inclined and somewhat unstable subaqueous slopes of the clino environment. Fig. 49 is a photograph of some large slump or flow markings in the Georges Fork-Dirty Creek strata in northern Wagoner County. The clino environment of the McAlester Basin area was, for the most part, a

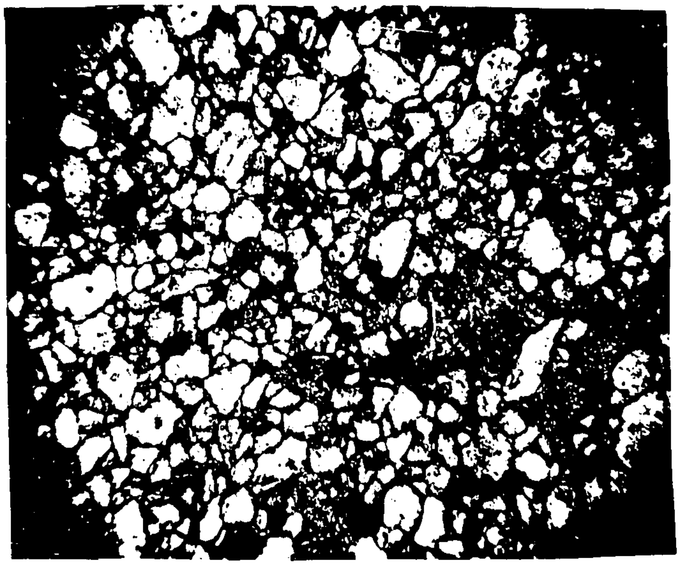


Fig. 48 -- Thin section of Pope Chapel sandstone, showing subangular quartz grains, many of which contain inclusions. SE¼ sec. 34, T. 15 N., R. 19 E., Muskogee County, Oklahoma. (X 25).

shallow water environment, for depositional criteria of shallow water realms near the strand line are numerous in these sediments.

Shales beneath the Georges Fork-Dirty Creek sequence are locally so crowded with carbonaceous plant remains and so characteristically lacking in marine fossils that they may be assumed to be, in part, nonmarine.

The Georges Fork-Dirty Creek sequence, as mapped in this study, is a subgraywacke sequence. The grain size averages somewhat finer than that of the Coody-Pope Chapel sandstones, occurring in the fine sand, very fine sand, or coarse silt ranges. The sorting is only moderate in many of these sandstones, as a result of a fair range of particle size variation. Grains vary from subangular to subrounded, as is commonly the case for sediments of finer grain sizes. Clay and iron oxide are

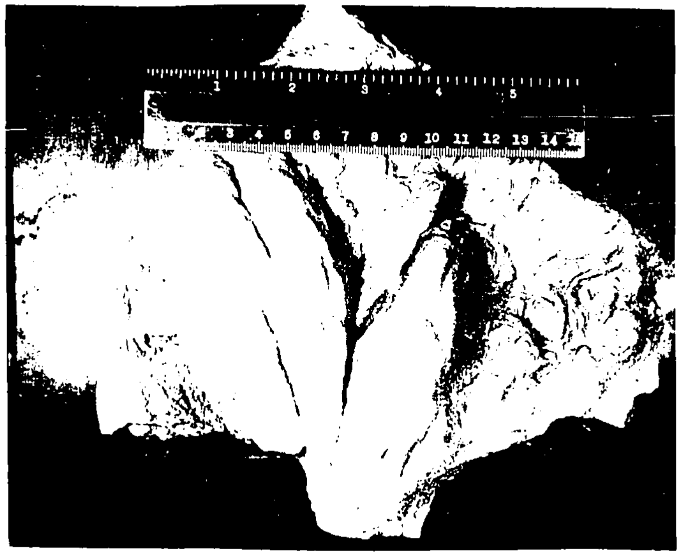


Fig. 49 -- Slump or flow markings in sandstone of the Georges Fork-Dirty Creek sequence, SE¼ NE¼ sec. 4, T. 17 N., R. 19 E., Wagoner County, Oklahoma. Such markings may represent sudden sliding or slumping of masses of water-soaked sediment on an unstable subaqueous slope.

abundant in the matrix, and secondary silica constitutes an important element of the cement in many cases.

Rocks of this sequence were apparently deposited on an unstable shelf in fairly shallow marine waters. Although shallow water deposition is indicated, the subsidence of the shelf and the accumulation of sediments was sufficiently rapid to depress the sediments beneath the level of effective wave base and to prohibit a thorough winnowing action by waves and currents. The dirty appearance of many of these sediments is a result of the contained clay, iron oxide, and rock fragment matrix, which was not removed by the sifting action of the transporting agents.

In many cases, the freshly broken surfaces of these sandstones exhibit a quartzitic appearance due to the secondary silica cement; many weathered surfaces are dense and dark brown with a case-hardened appearance. Taonurus markings are probably more abundant in rocks of this sequence than in any of the other Atoka members; such markings are believed to constitute a shallow water indicator. Fig. 50 is a photograph of Taonurus markings on a piece of Georges Fork-Dirty Creek float found at a time of low water level in the bed of the Verdigris River approximately ½ mile south of Okay, Oklahoma.

Chert pebble conglomerates are found at the base of the Georges Fork-Dirty Creek interval in many areas and denote rapid erosion of highlands to the northeast in the Ozark region early in the depositional history of this sequence. Later sediments, with finer grain size, denote a more subdued source area, which tended to remain low during the time that Georges Fork-Dirty Creek deposition was in progress in the McAlester Basin and on its unstable northern shelf area.

The most distinctive Atoka unit is the Webbers Falls member, consisting of siltstones, limestones, and shales. The siltstones range from light-colored varieties, showing fracture type bedding, and in many instances riddled with holes, to dark calcareous and carbonaceous types, with even bedding and well-developed joint patterns. The limestones range from calcarenites and fossiliferous fragmental varieties, at many places intimately associated with light-colored vesicular siltstones, to dark argillaceous fragmental types, and dark lithographic nodular limestones associated with black shales.

The various lithologies of the Webbers Falls member were deposited in differing, though closely adjacent, environmental realms. The dark-colored calcareous siltstones with abundant carbon content suggest quiet

Fig. 50 -- Taonurus markings on a piece of Georges Fork-Dirty Creek sandstone float found in the bed of the Verdigris River about ½ mile south of Okay, Oklahoma.

water depositional sites, perhaps lagoons or isolated bay areas. Somewhat stagnant waters may have existed in such areas so that scavenger activity was restricted. Lack of abundant scavengers seems to be indicated by the fair abundance of carbonaceous flakes and wisps in these Webbers Falls siltstones, and stagnancy of waters is suggested by pyritized gastropods in the shales beneath the Webbers Falls member. Fossils found in this facies of the Webbers Falls member include impressions of cephalopods, impressions of pectinoid pelecypods, small gastropods, "worm" markings, and Taonurus markings.

Source areas were subdued during Webbers Falls deposition. Many of the Webbers Falls siltstones probably accumulated in open waters at considerable distances from shore. This is indicated by fineness of grain of the sediment and the presence of pectinoid pelecypods and cephalopods, which are suggestive of open water habitats; however, these fossils may indicate representatives of a thanatocoenose which drifted into a somewhat stagnant water environment after death. The stagnancy of water in areas where dark-colored Webbers Falls siltstones accumulated may not be related as much to isolated lagoons or bays as to areas of open water that were characterized by profuse algal growths.

The light-colored Webbers Falls siltstones are at places characterized by many vesicles as a result of the surface or near-surface leaching of zones of limestone or zones of exceptionally high carbonate concentration in the siltstone. A hand specimen of Webbers Falls siltstone exhibiting this lithology is shown in Fig. 51. The dark-colored siltstones, though containing a slight carbonate component, has this carbonate content rather uniformly distributed through the rock, whereas the light-colored siltstones are characterized by a localization of carbonate content. Many of the light-colored siltstones have irregular masses or "cores" of calcarenite, and in areas where this core limestone has been leached, a vesicular texture results, imparting a "termite riddled" appearance to the rock. Figs. 16, 17, 18, 19, 20, 25, 26, 31, 32, and 35 are illustrative of such vesicular facies. The vesicles characteristically contain a fine limonitic-stained insoluble residue remaining "in place" as a result of the slow removal of the soluble limestone by ground water.

The light-colored limestones of the Webbers Falls also possess black, irregular, somewhat wavy wisps and streaks of carbon.

Certain of the light-colored siltstones have zones of light greenish-gray chert. This chert in thin sections is seen to consist of matted

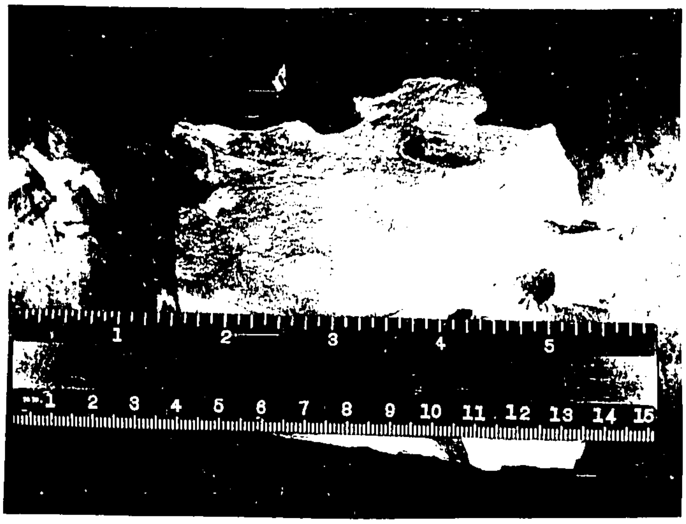


Fig. 51 -- Vesicular Webbers Falls siltstone with solution holes lined with a limonitic insoluble residue. NE¼ sec. 21, T. 17 N., R. 19 E., Wagoner County, Oklahoma.

spicules of sponges or spines of echinoids as shown in Fig. 52. Pectinoid pelecypod impressions are fairly abundant in the light-colored siltstones, suggesting the possibility of a depositional realm at some considerable distance from shore. The combination of diminished carbon content, the fineness of grain, the fossil evidence afforded by pectinoid pelecypods, and the calcarenite type of "core limestones," suggests a normal marine offshore depositional site. This is in contrast to the dark-colored siltstones, which suggest rather restricted, quiet, and possibly more stagnant waters.

The dark argillaceous fragmental limestones were deposited in shallow waters receiving a considerable influx of mud from adjacent land areas, as were also the nodular lithographic limestones in the associated black shales. Both types of limestone appear to be typical of somewhat

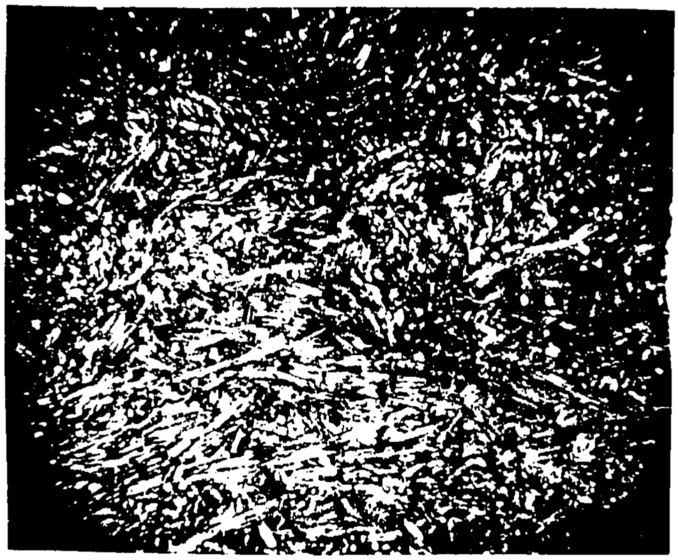


Fig. 52 -- Thin section of Webbers Falls chert showing matted and interwoven spicules (X 25). SE¼ sec. 7, T. 17 N., R. 19 E., Wagoner County, Oklahoma.

unstable shelf conditions (Krumbein and Sloss, 1951, p. 140 and pp. 362-363).

Webbers Falls limestones typically contain spines, echinoderm fragments, and at places, bryozoan and brachiopod fragments. Figs. 53, 54, 55, 56, 57, and 58 are photographs of thin sections of selected Webbers Falls limestones and siltstones. Some Webbers Falls calcarenite types contain glauconite grains in fair abundance, while argillaceous types contain clay minerals and carbonaceous flakes and bits.

The sandstones of the Blackjack School member appear to belong to the quartz-muscovite type of Dapples (1947, pp. 95-96). They are characterized by quartz and muscovite as the principal minerals, with quartz and iron oxide as cementing materials. Sorting is only moderate. In certain areas, such as in sections 1 and 12 of T. 17 N., R. 18 E., east

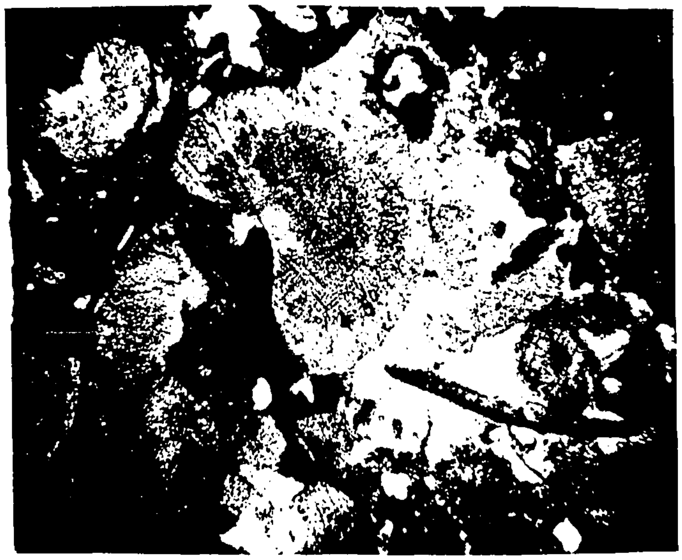


Fig. 53 -- Thin section of Webbers Falls limestone, showing numerous echinoderm elements (X 25). Near NW corner SE¼ sec. 23, T. 16 N., R. 19 E., Corwyn Ranch, Wagoner County, Oklahoma.

Fig. 54 -- Thin section of Webbers Falls limestone, showing echinoderm, bryozoan, and brachiopodal materials, and associated silt particles (X 25). Near NW corner SE¼ sec. 23, T. 16 N., R. 19 E. Wagoner County, Oklahoma.

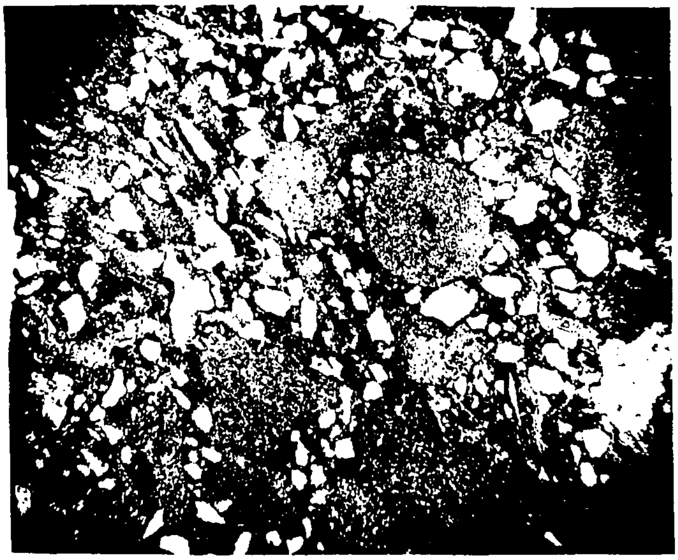


Fig. 55 -- Thin section of silty Webbers Falls limestone. Note echinoderm materials and angular to subangular silt particles. NW¼ sec. 20, T. 18 N., R. 19 E., Wagoner County, Oklahoma (X 25).

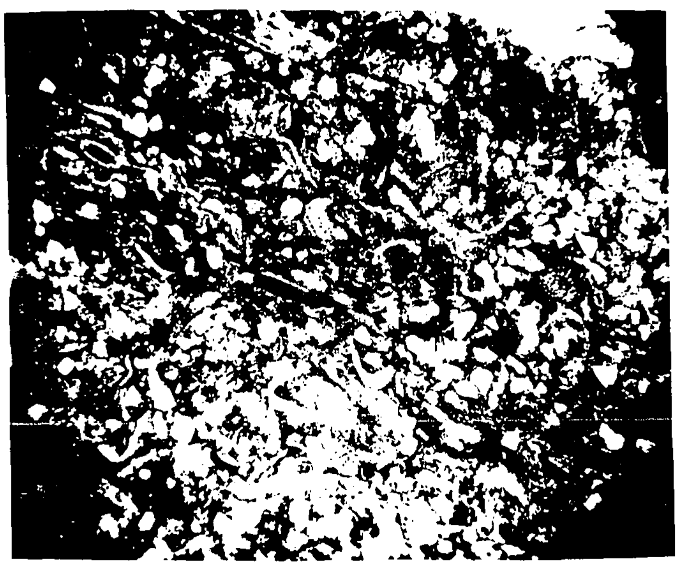


Fig. 56 -- Thin section of Webbers Falls limestone showing subangular to subrounded sand grains, abundant spicules, and fusulinid (X 25). Near C.N.L. sec. 34, T. 16 N., R. 19 E., Wagoner County, Oklahoma.

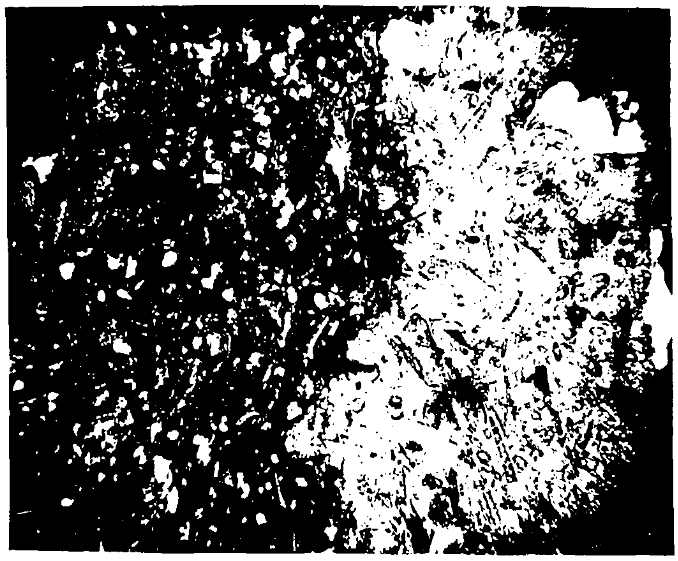


Fig. 57 -- Thin section showing the contact between Webbers Falls siltstone (dark) and limestone (light). Note spicular elements in the limestone (X 25). NE¼ sec. 23, T. 20 N., R. 18 E., Mayes County, Oklahoma.

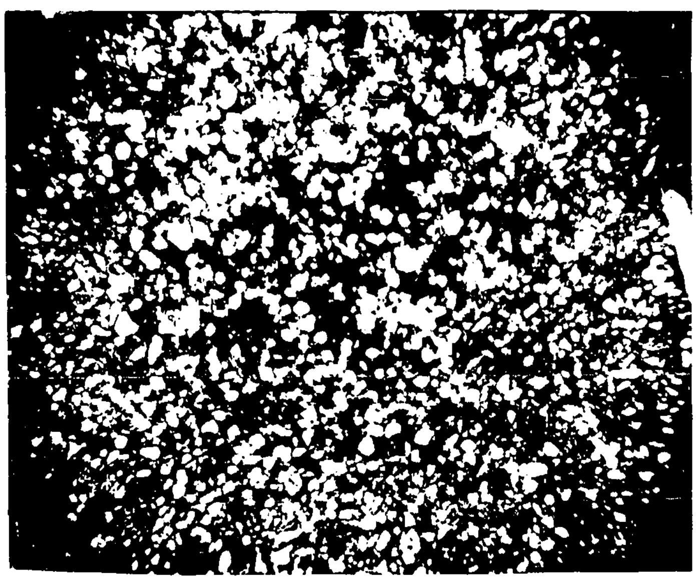


Fig. 58 -- Thin section of Webbers Falls siltstone (X 25). SE¼ sec. 32, T. 18 N., R. 19 E., Wagoner County, Oklahoma.

Fig. 59 -- Thin section of Blackjack School organic bituminous limestone. Note honeycomb pattern of calcite in the many echinoderm fragments. NE corner sec. 7, T. 21 N., R. 19 E., near Pryor, Mayes County, Oklahoma. (X 25).

Fig. 60 -- Thin section of Blackjack School organic bituminous limestone crowded with echinoderm fragments. NE corner sec. 7, T. 21 N., R. 19 E., near Pryor, Mayes County, Oklahoma. (X 25).

of Wagoner, and in sections 21 and 22 of T. 25 N., R. 21 E., east of Vinita,conglomerates are locally present at the base of the Blackjack School. A Blackjack School conglomerate of rather large pebbles of chert is shown in Fig. 47. This conglomerate caps a ridge near the center of a graben in SE¼ sec. 30, T. 18 N., R. 19 E., in Wagoner County.

Thin, ferruginous, fossiliferous limestones are present locally in the Blackjack School section and have been observed in sporadic occurrence from the area near Vian on the south to the area of Atoka disappearance north of Adair on the north. Fossils in these limestones commonly consist of Neospirifer and productid brachiopods, echinoderm fragments and spines, bryozoan remains, and fusulinid fragments. Figs. 59, 60, and 61 are photographs of thin sections of Blackjack School limestones, showing their typical organic nature.

Dapples (1947, p. 95) described the quartz-muscovite type sandstones as "sediments which appear to have accumulated chiefly in an environment associated with large alluviating rivers emptying into regions of extensive tidal flats." Plant fragments and molds of brachiopods occur rather abundantly in some facies of the Blackjack School sandstones. Cross-bedding, ripple marks, and Taonurus markings all suggest shallow water environments. Lack of uniform conditions of current flow and wave agitation are evidenced by the fair percentage of interstitial fine grains comprising a matrix in which the more abundant coarser grains are contained. As a result of variations in current flow, the sandstones of the Blackjack School are thicker in some areas and thinner in others, giving rise to considerable thickness variation in the member as a whole; thus, some areas are characterized by thick sandstone sequences and

Fig. 61 -- Thin section of Blackjack School ferruginous limestone. Note fusulinids and bryozoan materials. NW¼ NE¼ sec. 23, T. 23 N., R. 19 E., Mayes County, Oklahoma. (X 25).

others by only thin sandstones and correspondingly thicker shale sequences containing several thin fossiliferous and ferruginous limestones.

The Blackjack School sandstones are believed to indicate a slightly unstable shelf-type environment existing at the time when the Atoka seas had their maximum extent.

CHAPTER IV

STRUCTURE

The broad regional structures which were in existence in eastern Oklahoma, Arkansas, southern Missouri, and southeastern Kansas during Atokan time have been discussed previously. These included the following: (1) the area of the newly uplifted Ouachita Mountains south of the McAlester Basin in southeastern Oklahoma and southern Arkansas; (2) the McAlester Basin, which extended from the general area of Coalgate and McAlester, in southeast central Oklahoma, through Poteau and Sallisaw, in eastern Oklahoma, to Booneville, Danville, Perryville, and Morrilton in west central Arkansas; (3) the broad northern shelf area of northeastern Oklahoma and probably portions of northwestern Arkansas, marginal to the McAlester Basin, and probably characterized by a measure of tectonic instability; (4) the Ozark Uplift in northern Arkansas and southern Missouri, which had existed as a positive tectonic feature throughout most of Paleozoic time; (5) the Bourbon Arch, which extended across portions of Bourbon, Allen, Woodson, Coffey, and Lyon Counties in southeastern Kansas; and (6) the craton of northern Oklahoma, Kansas, and other central states.

The positive tectonic features in this assemblage included the Ouachita Mountains to the south, the Ozark area to the northeast, and the Bourbon Arch to the north of the northeastern Oklahoma shelf. The McAlester Basin subsided slowly and received thousands of feet of Atoka sandstones and shales, all of which give evidence of having accumulated in very shallow marine waters and on broad swampy alluvial plains sloping northward to the Atoka sea. The northeastern Oklahoma shelf area was presumably submerged by marine waters during most of Atokan time, but the Atoka seas were, in general, shallow, as judged by the lithologic and paleontologic criteria available.

Weirich (1953, p. 2032) demonstrated that a "hinge line" apparently existed between the northeastern Oklahoma shelf area and the McAlester Basin during Atoka time. Other hinge lines, occupying locations farther to the north and northwest of the Atoka hinge line, existed during Desmoinesian time, separating areas of shelf and basinal facies (ibid., pp. 2033-2045).

The unconformity between the Atoka formation and the underlying Lower Pennsylvanian and Upper Mississippian rocks is post-Morrow, pre-Atoka, and thus appears to be correlative with the main Wichita orogeny of Van der Gracht (1931, pp. 991-1057).

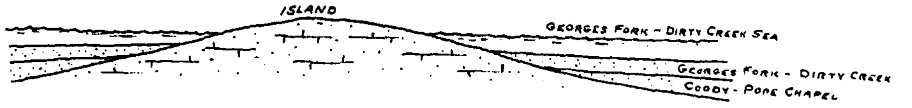
Other structural features of significance in a discussion of the Atoka formation of the northeastern Oklahoma shelf area are of smaller scale. Some were in existence while the Atoka sediments were accumulating; others are post-Atoka structures which serve to affect present-day distribution of Atoka exposures.

During Atokan time numerous small hills of Morrowan and older rocks protruded from the Atokan seas as small island masses. Certain of these hills were not submerged until Georges Fork-Dirty Creek time and others remained above the sea until Webbers Falls time. No examples have been found of hills which escaped Webbers Falls submergence in the general area occupied by the Webbers Falls seas in Wagoner and Mayes Counties.

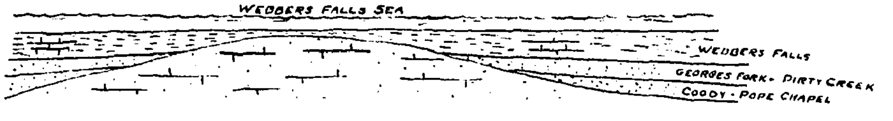
In sections 6 and 7 of T. 18 N., R. 19 E., and sections 1 and 2 of T. 18 N., R. 18 E., a hill of Morrow strata apparently remained emergent until Webbers Falls time. In this general area, the highest portions of the former hill show Webbers Falls shales overlying Hale calcarenite.

Generalized cross-sections are shown in Fig. 62 to illustrate the following events: (1) the hill remained emergent in the Atoka seas until Webbers Falls time; lower Atoka units of the Coody-Pope Chapel and the Georges Fork-Dirty Creek were deposited about its flanks; (2) in Webbers Falls time, the Atoka seas submerged the hill, depositing the shales and nodular limestones of the Webbers Falls member across the crest of the hill, followed by the deposition of Blackjack School and younger Pennsylvanian sediments; (3) regional tilting to the west in Mesozoic time and subsequent erosion to the present.

Another area of Morrow strata which was only partially submerged during Georges Fork-Dirty Creek time is an area in southern Mayes County in sections 1, 11, and 12, T. 19 N., R. 18 E., and sections 6 and 7, T. 19 N., R. 19 E. In the east ½ of sec. 11, T. 19 N., R. 18 E., Webbers Falls limestones rest upon Morrow limestones, indicating that perhaps complete overlap did not occur until Webbers Falls time. Over most of the area mentioned, however, thin Georges Fork-Dirty Creek facies rest



(1) Georges Fork-Dirty Creek time; island of Hale limestone in Georges Fork-Dirty Creek sea.



(2) Webbers Falls time; submergence of former island and deposition of Webbers Falls member.

(3) Regional tilting to the west in Mesozoic time, and subsequent erosion to yield present topography.

Fig. 62 -- Diagrams to illustrate sequence of events involved in the formation of present-day inliers of Morrow limestone in Atoka terrains.

unconformably upon limestones and calcarenites of the Hale formation.

Mention was made in Chapter II of the thin shale section present between the Webbers Falls siltstones and the basal conglomeratic sandstone of the Blackjack School in the NE¼ sec. 12, T. 17 N., R. 18 E. and the SE¼ sec. 1, T. 17 N., R. 19 E. The Webbers Falls siltstones are also thin in this area, although the Georges Fork-Dirty Creek sequence apparently attains normal thicknesses. These facts suggest that this area was subjected to slight uplift during Webbers Falls time, with the result that the Webbers Falls sediments were not deposited in normal thickness in this area. This general area today constitutes part of a small dome located principally in sections 1, 11, 12, and 13 of T. 17 N., R. 18 E., and sections 5, 6, 7, 8, 17, and 18 of T. 17 N., R. 19 E., east of Wagoner. The dome exposes Georges Fork-Dirty Creek sandstone across the topographic crest, and Webbers Falls and Blackjack School members on the flanks. The oldest Atoka exposed on the dome is the Coody-Pope Chapel facies, which is partially exposed in the NE¼ sec. 7 and the SE¼ sec. 6, T. 17 N., R. 19 E. The latitude of this exposure corresponds with that of the thin Webbers Falls section mentioned previously and thus accords with the assumption that this specific area marks the axis of a very slight uplift which occurred during Atoka time, probably during Webbers Falls deposition. The southward shifting of the present dome crest is the result of slight northward tilting which accompanied the faulting. The area constitutes the upthrown side of a postulated northeast-southwest fault which is believed to extend through sections 7 and 8 of T. 17 N., R. 19 E. Northwestward tilting of the fault block caused a shift in the crestal position from the area of thin Webbers Falls section to the present location of Georges Fork-Dirty Creek outcrop in the W½ sec. 7, T. 17 N., R. 19 E. The folding is seen to have preceded the faulting in this area.

Another small dome involving Atoka strata is located approximately 2 miles northwest of Chouteau, Oklahoma, in sections 8, 9, 10, 15, 16, and 17, T. 20 N., R. 18 E. This dome has been breached by Chouteau Creek, and exposes the Fayetteville shales and lithographic limestones along a short interval of stream floor. Above the Fayetteville formation lies a thin interval of Coody-Pope Chapel facies, which constitutes the northernmost exposure of definitely recognized Coody-Pope Chapel facies in Mayes County. The Georges Fork-Dirty Creek sequence and the Webbers Falls sequence are thin in this area, and the area also marks the approximate latitude of the northernmost definitely recognized exposures of the Webbers Falls siltstones and limestones.

The dome is situated to the west of a northeast-southwestward trending fault, and serves to expose the Fayetteville and Atoka units in an area where normally Desmoinesian units constitute the surface formations.

Approximately 3½ miles northwest of Wagoner, the West Wagoner Oil Field is located on a domal structure formed on a horst. The horst is bounded on the southeast and northwest by faults which trend northeast-southwestward. The crest of this uplift exposes Georges Fork-Dirty Creek strata. Topographically lower, but stratigraphically higher, are exposures of Webbers Falls siltstones and calcarenites, and ferruginous limestones and sandstones of the Blackjack School sequence.

The most prominent faults in northeastern Oklahoma strike in general northeast-southwestward, and have resulted in a horst and graben structure. The most prominent of the large faults in northeastern Oklahoma is the double fault that bounds the Seneca graben and extends through Ottawa County and northwestern Delaware County into Mayes County. In a portion of this distance it is present beneath the waters of Grand Lake and the spillway of Pensacola Dam. Northeast of Pryor, in Township 22 N., the Seneca Graben preserves Atoka sandstone units belonging to the Dirty Creek, and possibly, the Pope Chapel facies. Although the structure is that of a graben, the area is, in part, a subdued topographic ridge, due to subsequent erosion etching into relief those portions of the graben in which the resistant sandstones of the Atoka formation are preserved. Elsewhere, where the Atoka sandstones have been completely removed, the graben has little topographic relief either positive or negative.

Although the folding and faulting of the northeastern Oklahoma shelf and the southwestern flank of the Ozark Uplift may be approximately synchronous, the evidence obtained from the dome a mile east of Wagoner, as recorded above, suggests that the folding probably shortly antedated the faulting. If exactly synchronous with the initial horst type faulting, subsequent movements occurred along the bounding fault to the southeast of the dome, as indicated by the southward shifting of the domal crest since Webbers Falls deposition.

Inasmuch as many of the domes and anticlines are associated with horst structures, an analogy may be drawn with the fault-folding or bruchfaltung type structure of portions of middle and north Germany

(Hills, 1953 pp. 68-69). The analogy is only partial, due to the fact that the folding apparently does not increase in the downthrown blocks, as is the case in Saxony.

The horst and graben type faulting suggests that the faults are normal faults and that tensional forces have been responsible for their formation. Most of these faults are post-Atoka and post-Boggy, but pre-Senora, inasmuch as Atoka, Spaniard, and Boggy formations are cut by the faults, but the Senora formation is not affected by the faulting. Movements along many of these faults has probably been recurrent, inasmuch as pre-Atoka units have been offset more than Atoka, Hartshorne, McAlester, Savanna, and Boggy units (Wilson and Newell, 1937, pp. 74-75). Some faults which transect Mississippian and older units apparently do not cut Atoka strata. The faults are, therefore, a result of movements which occurred in Mississippian, in post-Morrow, in Atoka, and in early Desmoinesian times.

In Desmoinesian time, the Ozark region on the east and northeast was being subjected to gentle uplift, the Nemaha Ridge on the west had appeared as a mountain ridge in the Desmoinesian sea, the Anadarko Basin and Ardmore Basin were subsiding in southwestern and south-central Oklahoma, and the McAlester Basin continued its subsidence to the south. Unequal amounts of torsional flexuring of the shelf area of northeastern Oklahoma undoubtedly resulted from the unequal subsidence and uplift of various adjacent Mid-Continent structures at this time.

Arbenz (1955, p. 23) suggested that the alignments of most of the prominent tectonic units of Oklahoma may reflect deformational trends established during Precambrian time and preserved in the Precambrian basement. He referred the northeast alignment of the tensional faults of northeastern Oklahoma to the "Ozark strike," a category of tectonic features which also includes the en-echelon faults of the Central Oklahoma platform, the northern Oklahoma portion of the Nemaha Ridge, the northeastward-striking fault pattern of the Arbuckle-Wichita system, the transverse modifications of the fold pattern of the Ouachita Mountains and the McAlester region, and the geophysical anomalies crossing the Anadarko Basin west of the Nemaha Ridge (Arbenz, 1955, p. 23).

McLaughlin (1954, pp. 287-289) suggested that the Grenville orogenic belt, established during Precambrian time, may have extended along the area of the Cincinnati Arch and Nashville Dome, and curved westward near the Mississippi River to include the Ozark Uplift. He further surmised that an enormous fault offsets the western segment of the belt northward 200 miles or more, thus accounting for the present discrepancy in the trends of the Ouachita and Appalachian folded belts (ibid.). He suggested that this fault is a continuation of the Grenville Front in Canada. This is an example of the type of thinking which is currently being employed to explore the relationship between present-day structural features and Precambrian tectonic trends.

Although the greatest number of prominent northeastern Oklahoma faults trend northeast-southwestward, a few faults, as would be expected, possess a northwest-southeastward trend. One such fault is mapped in southern Mayes County in the general area where the Atoka formation locally rests upon the Fayetteville formation. Fig. 63 shows a steeply-dipping section of Morrow limestone involved in the zone of drag along this fault.

Fig. 63 -- Steeply-dipping Morrow limestone involved in the zone of drag along a northwest-southeast fault in SW¼ sec. 16, T. 19 N., R. 19 E., Mayes County, Oklahoma.

Joint patterns of Atoka members have not been accurately mapped, but the general trend of joints in the Webbers Falls member is at places as follows: one set trending slightly north of west and the other set practically due north.

In conclusion, it may be surmised that the northeastward strike of the normal faults of northeastern Oklahoma roughly parallels the axis of the Ozark Uplift in Oklahoma. This axis is believed to be essentially parallel to a line from Tahlequah, in Cherokee County, to Eufaula, in McIntosh County, and is suggested by the direction of strike of the Senora, Stuart, and Thurman formations in McIntosh, Pittsburgh, and Hughes Counties, and perhaps by the northeastward flow of the Canadian River in Hughes County. Although these trends are also due, in part, to the strike of the Ouachita folded belt, it is believed that such trends suggest a composite adjustment, with the Precambrian alignments of the Ozark Uplift existing as one of the prime factors accounting for the prevalent northeastward strikes of present-day northeastern Oklahoma structures.

CHAPTER V

THE FOSSIL FAUNA AND FLORA OF THE ATOKA FORMATION

Beds containing abundant fossil remains are only sparsely represented in the Atoka formation. In Oklahoma three noteworthy Atokan localities have yielded excellent faunules. The first of these is located in the upper Atoka black shales south of Red Oak in Latimer County, where collections have been made and the microfaunule described by Galloway and Rynicker (1930, pp. 1-37). The second prominent locality is located near Clarita in southwestern Coal County and in the northwestern corner of the Atoka Quadrangle. The faunule from this area has been described by Mather (1917, pp. 133-139). An excellent cephalopod assemblage has been collected from this area by Denison and is located in the paleontological repositories of the School of Geology at the University of Oklahoma. The third locality is the road cut of Oklahoma State Highway 51 at the eastern end of the bridge over Fort Gibson Lake in NE¼ NE¼ sec. 27, T. 17 N., R. 19 E., in Cherokee County. Collections from this locality were made by Dobervich (1951) in the course of his investigations in the Hulbert area, and by Dr. C. C. Branson and the writer during the present investigation. Fig. 29 is a photograph of some of the fossiliferous shales at this locality.

The Red Oak locality of Galloway and Rynicker is described as a thin bed of clay shale, 500 feet below the top of the Atoka formation, near the middle of the north line of sec. 11, T. 5 N., R. 21 E., southeast of Red Oak in Latimer County (Galloway and Rynicker, 1930, p. 5).

The fauna is described as being dwarfed, consisting of algae, Foraminifera, sponges, crinoid fragments, brachiopods, Bryozoa, gastropods, pelecypods, and ostracodes (ibid.).

The fusulinids, Staffella, Schurbertella, and Fusulinella, are described (ibid., pp. 22-26). Mention is made of the fact that most of the Atoka Foraminifera are calcareous, with Tolypammina and Nodosinella constituting the only two exceptions (ibid., p. 6).

The conclusion is reached that Pennsylvanian Foraminifera, in general, possess long ranges, and that it is more practical to attempt correlations on the basis of faunal assemblages rather than on individual species (ibid.).

The Clarita locality is north of the old Barnett house in sec. 2, T. 1 S., R. 8 E., on the north edge of Clarita, in southwestern Coal County. In this area, beds of calcareous sandstone near the base of the Atoka formation contain many molds and casts of cephalopods, pelecypods, gastropods, and brachiopods, as well as corals and Bryozoa.

Mather (1917, pp. 133-139) listed 42 identified forms from this area, 33 species of which are known to occur elsewhere, and 20 of which have been described from the Morrow group of the Ozark region. The 42 species cited by Mather as comprising the Atoka faunule at Clarita are listed below. Those species in the list which have been described by Mather from the Morrow group of the Ozark region (1915, Table I) are preceded by the letter "M".

<u>Faunule from the Atoka Formation at Clarita, Oklahoma.</u>

M Campophyllum torquium (Owen)
M Rhombopora sp.
M Prismopora concava Mather
M Chonetes choteauensis Mather
M Chonetes laevis Keyes
M Productus fayettevillensis Mather
M Productus gallatinensis ? Girty
M Spirifer rockymontanus Marcou
M Squamularia perplexa (McChesney)
M Composita wasatchensis (White)
M Nucula parva McChesney
Yoldia glabra ? Beede and Rogers
M Parallelodon pergibbosus Mather
Caneyella ? n. sp.
M Pseudomonotis precursor Mather
M Myalina cuneiformis Gurley
M Myalina orthonota Mather
Schizodus affinis Herrick
Schizodus wheeleri ? (Swallow)
Schizodus telliniformis Girty
M Deltopecten occidentalis (Shumard)
M Aviculopecten arkansanus Mather
Plagiostoma ? acosta Cox
Pleurophorus subcostatus ? Meek and Worthen
Pleurophorus n. sp.
Pleurophorus sp.
Astartella n. sp.
M Euphemus carbonarius (Cox)
M Worthenia tabulata (Conrad)
Orestes sp.
Euconospira turbiniformis (Meek and Worthen)
Strophostylus remex (White)
M Platyceras parvum (Swallow)
M Aclisina ? sp.
M Orthoceras sp.
Metacoceras sp.
Pronorites cyclolobus var. arkansasensis Smith
Gastrioceras listeri (Martin)
Gastrioceras hyattianum Girty
Gastrioceras angulatum Girty
Gastrioceras carbonarium von Buch
M Gastrioceras kesslerense Mather

In addition to the 20 species preceded by "M" in the list above, <u>Pronorites cyclobus</u> var. <u>arkansasensis</u> Smith, now <u>Pronorites arkansasensis</u> Smith, has been described from the Hale formation of Arkansas and from the Bend series in Texas. Strophostylus remex was described by Mather (1917, pp. 133-139) as present in the Lower Aubrey group of Utah, an interval which appears to be closely correlative with the Morrow.

The other forms of the list occur also in Pennsylvanian strata above the Morrow in Oklahoma, and adjacent regions, and some are found in Permian strata.

A faunule collected from this locality by A. R. Denison is contained in the paleontological repository of the School of Geology of the University of Oklahoma and includes these forms:

Crurithyris planoconvexa (Shumard)
Composita ovata Mather
Hustedia miseri Mather
Hustedia mormoni (Marcou)
Punctospirifer kentuckyensis (Shumard)
Spirifer opimus Hall
Spirifer rockymontanus Marcou
Euphemites (?) nodocarinatus (?) (Hall)
Trepospira depressa (Cox)
Allorisma terminale Hall
Eoasianites globulosus (Meek and Worthen)
Owenoceras hyattianus (Girty)
Paralegoceras iowense (Meek and Worthen)
Pronorites sp.
Crinoid stems

Fig. 64 is a photograph of the cephalopod Pronorites from this locality.

Before discussing the faunule from the area near Fort Gibson Lake, it is desirable to consider briefly some of the work accomplished by other workers on Atokan faunas in other parts of the United States.

Plummer and Moore (1921, pp. 57-59) described the fauna of the Smithwick shale of north-central Texas. They emphasized that the fauna is predominantly molluscan and that most of its elements are distinctly Pennsylvanian. Species of the gastropod Bellerophon and the cephalopod

Fig. 64 -- Pronorites from the Atoka formation at Clarita, Oklahoma (X 1).

Gastrioceras compressum are the most common forms present. A more recent work by Plummer (1943, p. 82) listed 8 corals, 1 bryozoan, 11 brachiopods, 11 pelecypods, 12 gastropods, 7 pseudoorthoceratites, 6 nautiloids, and 11 ammonoids from the Smithwick formation.

The description by Plummer and Moore (1921, pp. 44-55) of the fauna of the underlying Marble Falls limestone in north-central Texas serves to demonstrate its transitional aspect, imparted by the residual Mississippian elements and the proemial Pennsylvanian elements present. Plummer (1953, pp. 69-70) listed 8 corals, 31 brachiopods, 13 pelecypods, 7 gastropods, 7 nautiloids, 3 ammonoids, and 1 orthoceratoid cephalopod from the Lemons Bluff member of the Big Saline formation of the Marble Falls limestone.

Spivey and Roberts (1946, pp. 181-186) presented faunal evidence that the Marble Falls limestone is post-Morrow in age and equivalent to a portion of the Atoka formation. On the basis of the evidence presented, they suggested that the Atoka formation be raised to series rank. Thus, the Atoka series would replace the Lampasas series that had previously been defined. Evidence was presented that the Lampasas series, as previously defined, included some strata of Desmoinesian age and excluded the lower portion of the Marble Falls limestone, which they suggested is entirely of Atokan age (Spivey and Roberts, 1946, pp. 181-186). Plummer (1943, pp. 47 and 52), on the other hand, assigned the Sloan formation of the lower Marble Falls to the Morrowan series, and the Big Saline formation of the Marble Falls to the Atokan series.

Spivey and Roberts (1946, pp. 181-186) suggested that the fusulinid zones which occur within the Atokan interval are the zone of restricted Fusulinella, and the zones of Fusiella, Profusulinella (?) Ozawainella, and Pseudostaffella. By comparison, they stated that the Desmoinesian section includes an advanced type of Fusulinella, as well as Fusulina and Wedekindellina, whereas the Morrowan series is identified by the abundance of Millerella and the absence of more advanced fusulinids (ibid.).

In New Mexico, Thompson demonstrated that the Derry series is approximately the equivalent of the Atokan series of Oklahoma (Thompson, 1942, p. 28). Rocks of the Derry series in New Mexico have yielded the fusulinids Millerella, Nankinella, Staffella, Eoschubertella, Profusulinella, Pseudostaffella, Fusulinella, and Fusulina ? (Thompson, 1948, p. 75). Thompson (1942, p. 29) noted that although representatives of Fusulinella occur in the uppermost portion of the Derry series and are present throughout Desmoinesian strata, a closely related group of species of _Fusulinella_ appears to be limited in its distribution to a restricted portion of the upper Derry series. Other parts of the Derry series contain certain groups of species of the genus _Profusulinella_ and certain species of _Eoschubertella_.

According to Kottlowski, Flower, Thompson, and Foster (1956, p. 37), the zone of _Profusulinella_ is found principally in the lower portion of the Derryan series. It was declared that although _Fusulinella_ occurs in upper Derryan and lower Desmoinesian strata, in Desmoinesian rocks it is invariably associated with _Fusulina_.

Morningstar (1922) described the fauna of the Pottsville series of Ohio, and her complete faunal list shows a predominance of pelecypods and gastropods (pp. 139-144).

Croneis (1930, p. 135) presented three lists of fossils collected by Collier from the upper part of the Atoka formation near Van Buren, Arkansas, and Morgan (1924, pp. 64-65) included two brief lists of Atoka fossils from the western part of the Coalgate quadrangle in south-central Oklahoma.

The "Morrow fauna" listed by Honess (1924, pp. 14-16) as occurring in the Jackfork sandstone was interpreted by Croneis (1930, pp. 136-137) as an Atoka fauna.

A Lower Pennsylvanian fauna has been described by Kelly (1930, pp. 129-151) from the Saginaw formation of Michigan, and Morse (1931, pp. 298-301) described a fauna of distinctly Lower Pennsylvanian aspect from the Kendrick shale of Kentucky. These faunas possibly indicate a partial equivalence of the formations in which they are found and the Atoka formation of Oklahoma.

One of the finest Atoka collecting localities in Oklahoma is found in the black shales associated with the Webbers Falls member in the NE¼ NE¼ sec. 27, T. 17 N., R. 19 E., Cherokee County, Oklahoma, in the road cut at the eastern end of the Oklahoma State Highway 51 bridge over Fort Gibson Lake. The faunule collected from this locality is listed below.

Atoka Faunule, Oklahoma State Highway 51, NE¼ NE¼ sec. 27, T. 17 N., R. 19 E., Cherokee County

Coelenterata
- Calloconularia ? sp.
- Paraconularia cf. crustula (White)
- Lophophyllidium cf. wewokanum Jeffords
- Pleurodictyum eugeneae White

Bryozoa
- Unidentified lacy Bryozoa
- Rhombopora lepidodendroides Meek

Echinoderma
- Ethelocrinus magister Miller and Gurley
- Delocrinus verus ? Moore and Plummer
- Crinoid columnals
- Paragassizocrinus epycylix, n. sp.
- Echinoid spine (Echinocrinus ?)

Brachiopoda
- Chonetinella flemingi var. plebeia ? Dunbar and Condra
- Chonetes granulifer Owen
- Chonetes granulifer var. armatus ? Girty
- Cleiothyridina orbicularis (McChesney)
- Composita argentea (Shepard)
- Composita elongata ? Dunbar and Condra
- Composita ovata ? Mather
- Composita subtilita Hall
- Crurithyris planoconvexa (Shumard)
- Derbyia cf. crassa (Meek and Hayden)
- "Dictyoclostus" cf. americanus Dunbar and Condra
- Hustedia mormoni ? (Marcou)
- Juresania nebrascensis (Owen)
- Lindstroemella ? patula ? (Girty)
- "Linoproductus" platyumbonus Dunbar and Condra
- Lissochonetes geinitzianus (Waagen)
- Marginifera cf. muricatina Dunbar and Condra
- Marginifera cf. missouriensis Girty

Marginifera cf. splendens (Norwood and Pratten)
Marginifera cf. wabashensis (Norwood and Pratten)
Neospirifer cameratus (Morton)
Neospirifer dunbari King
Orbiculoidea missouriensis (Shumard)
Punctospirifer kentuckyensis (Shumard)
Spirifer occidentalis Girty
Spirifer opimus ? Hall
Spirifer rockymontanus Marcou
Condrathyris perplexa ? (McChesney)
Trigonoglossa nebrascensis (Meek)

<u>Mollusca</u> -- <u>Pelecypoda</u> or <u>Lamellibranchiata</u>
Acanthopecten carboniferus (Stevens)
Anthraconeilo taffiana Girty
Astartella concentrica Conrad
Nucula anodontoides ? Meek
Nucula ? girtyi ? Schenck
Nuculana bellistriata (Stevens)
Nuculopsis ventricosa Hall
Pseudomonotis ? sp.
Schizodus cuneatus Meek
Schizodus wheeleri Swallow
Yoldia glabra Beede and Rogers

<u>Mollusca</u> -- <u>Gastropoda</u>
Amphiscapha catilloide (Conrad)
Bellerophon ? sp.
Euphemites carbonarius Cox
Glabrocingulum grayvillense (Norwood and Pratten)
Lepetopsis cf. parrishi Gurley
Strophostylus cf. girtyi (Knight)
Trepospira depressa Cox
Worthenia tabulata (Conrad)
Trachydomia cf. oweni Knight
An unidentifiable bellerophontid gastropod

<u>Mollusca</u> -- <u>Cephalopoda</u>
Mooreoceras sp.
Mooreoceras normale ? Miller, Dunbar, and Condra
Pseudoparalegoceras n. sp.
Unidentified cephalopods

<u>Chordata</u>
Deltodus sp.

<u>Plants</u>
Conostychus ? sp.
Petrified wood

Microfaunule:

Protozoa

Ammodiscus sp.
Orobias radiata ? (Brady)
Orobias ciscoensis ? (Harlton)
Tetrataxis plicata ? (Brady)

Arthropoda
Bairdia beedei ? Ulrich and Bassler
Bairdia crassa ? Harlton
Bairdia peracuta ? Warthin
Cavellina sp.
Amphissites girtyi ? Knight
Hollinella limbata ? (Moore)
Healdia longa ? Knight
Healdia fabalis ? Cooper
Healdia nucleolata ? Knight
Monoceratina ardmorensis ? (Harlton)
Paraparchites latidorsatus ? Warthin

Chordata ?
Polygnathus sp.

This faunule is predominantly a brachiopod and molluscan assemblage, as to numbers of species, but considering individual specimens, it has been noted that corals are probably the most abundant element present.

The solitary coral, Lophophyllidium cf. wewokanum, and the colonial coral, Pleurodictyum eugeneae, are present in approximately equal numbers. Another interesting coelenterate element present includes the conularids, Paraconularia cf. crustula and Calloconularia ? sp., represented by approximately six to eight individuals in the collections made from this locality.

The faunule, as a whole, is dominantly Pennsylvanian, but a few remnant Mississippian elements are present.

The fossils are abundant in the ferruginous limestones and overlying black shales. The abundant fossils in the black shale probably were suddenly entombed by an influx of mud as a black pall. It is known that many invertebrate marine organisms, such as corals, pelecypods, gastropods, etc., have a limit of silt or mud tolerance beyond which living conditions become relatively intolerable.

The absence of free-swimming pectinoid pelecypods and the presence of small burrowing pelecypods, numerous gastropods, brachiopods, and several fragments of petrified wood, suggest a shallow water, near shore environment. The plant Conostychus, probably a blue-green alga, is also suggestive of a shallow water, near shore realm. Similar evidence is possibly afforded in a negative manner, by the relatively few cephalopods present.

The area occupied by this faunule must have been situated near shore in close proximity to the ever positive Ozark area. In the shallow waters a short distance offshore, the prolific faunule flourished, only to be overcome by a black pall of mud which swept into the area as a result of a slight uplift in the adjacent Ozark Uplift to the northeast.

The cephalopods Mooreoceras, Pseudoparalegoceras, Gastrioceras and a few others unidentified forms are sparsely represented. Pieces of a coiled cephalopod from this locality were sent to Dr. A. G. Unklesbay for preliminary examination and his comments regarding the form are as follows:

> I believe these represent a new species of Pseudoparalegoceras. It is near to Pseudoparalegoceras brazoense but lacks constrictions. Unfortunately the external suture pattern is not clear. The small fragment has well preserved internal (dorsal) sutures of the whorl that is gone. Superficially, the large fragments resemble Paralegoceras texanum but the lateral ridges are absent and there is no assurance that the earlier coils were triangular. (A. G. Unklesbay, personal communication to Dr. C. C. Branson.)

Fig. 65 is a photograph of this cephalopod.

Fig. 65 -- Incomplete cephalopod from the Oklahoma State Highway 51 locality near Fort Gibson Lake. This specimen is believed to be a new species of Pseudoparalegoceras (X 1).

The echinoderm elements are represented by numerous columnals, relatively few calyx plates of Ethelocrinus and Delocrinus, and one fairly complete and two partial calices of Paragassizocrinus epycylix, n. sp. The most complete calyx is illustrated in Figs. 66 and 67, and a less complete calyx is shown in Fig. 68.

The description of the more complete specimen is as follows:

Paragassizocrinus epycylix, n. sp.

Height of dorsal cup	23 mm
Width of dorsal cup at the top	20 mm
Ratio of height to width	0.87
Length of basal	12 mm
Width of basal	12 mm
Length of radial	7 mm
Width of radial	13 mm
Length of suture between basals	8 mm
Length of suture between radials	5 mm
Height of infrabasal circlet	11 mm

Height of anal plate - - - - - - - - - - - - - - - - - -	6 mm
Width of anal plate - - - - - - - - - - - - - - - - - -	6 mm
Height of first primabrach - - - - - - - - - - - - - - -	4 mm
Height of second primabrach - - - - - - - - - - - - - - -	4.5 mm
Length of suture between 2nd primabrach and 1st secundibrach (along curvature) - - - - - - - - - - -	7.5 mm

Another cup, without radials, has these measurements:

Length of basal -	13 mm
Width of basal -	13 mm
Length of suture between basals - - - - - - - - - - - -	9 mm
Height of infrabasal circlet - - - - - - - - - - - - - -	14 mm

Two dissociated infrabasal cones have heights of 13 mm, one has a height of 10 mm, one of 7 mm, and one of 8.5 mm. The respective widths are 19 mm, 20 mm, 16 mm, and 12 mm. Dissociated basal plates which have been found have widths of 12.5 mm, 13.5 mm, and 9 mm, with respective heights of 15.5 mm, 14.5 mm (a posterior basal, i.e., beneath the anal plate), and 9 mm.

This new species of Paragassizocrinus resembles Paragassizocrinus tarri (Strimple) from the Missourian series, but differs from it in having somewhat larger dimensions of calyx height vs. width and greater length of infrabasals, basals, and radials.

The specific name means "tall cup" and refers to the appearance of the calyx which resembles a tall goblet. The name is a noun in apposition formed from the Greek aipos, high, and kylix, cup or goblet.

The microfaunal assemblage in the black shales of this locality is characterized principally by ostracods, many of which are relatively unornamented, and by spiral Foraminifera. Fusulinids were not noted in this faunule, although they are undoubtedly present in small numbers. Thin sections of limestones belonging to the overlying Blackjack School member reveal a moderate number of fusulinids, but generic identifications were not possible because of the random angles of sectioning. These facts suggest that fusulinids became more numerous during Atoka, Blackjack School, time as the Atokan seas attained their maximum extent and pelagic fusulinids attained greater distribution.

Approximately 18 feet higher in the section, in the vesicular siltstone facies of the Webbers Falls, an entirely different faunule is encountered. Approximately one mile west of the above-mentioned locality, in NE¼ sec. 21, T. 17 N., R. 19 E., a specimen of Aviculopecten providencis, a Derbyia, and a trilobite pygidium have been collected, whereas in the same facies, near the NW corner SW¼ sec. 19, T. 17 N., R. 19 E., a specimen of Acanthopecten carboniferus was collected. The pectinoid pelecypods are believed to indicate an open water realm at some distance from shore, and this contrasts with the near-shore environment suggested by the faunule of more abundant elements listed on pages 97-99.

The dark-colored Webbers Falls siltstones beneath the bridge of Oklahoma State Highway 2 at Okay, Oklahoma, exhibit an occasional pectinoid pelecypod, along with numerous sinuous carbonaceous wormlike markings. Though abundant carbon is present in these siltstones, the faunal evidence suggests an offshore depositional environment for the Webbers Falls siltstones.

The dark shales beneath and above the Webbers Falls siltstones at Okay contain a predominant brachiopod and molluscan assemblage.

The limestones of the Blackjack School member contain abundant Neospirifer cameratus and other brachiopods, and much crinoidal debris, but few molluscs. Fusulinids are rather numerous in the Blackjack School limestones, whereas they are rather sparsely represented in lower Atoka

Fig. 66 -- *Paragassizocrinus epycylix*, n. sp. from the Oklahoma State Highway 51 locality near Fort Gibson Lake (X 1).

Fig. 67 -- *Paragassizocrinus epycylix*, n. sp. from the Oklahoma State Highway 51 locality near Fort Gibson Lake (X 1).

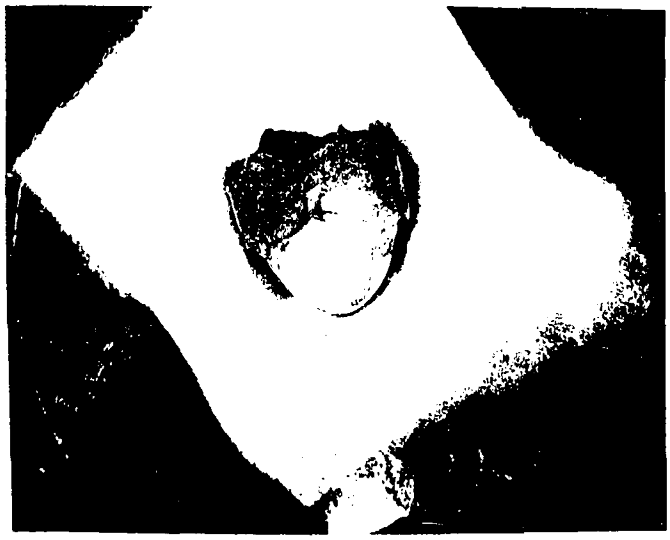


Fig. 68 -- Incomplete calyx of Paragassizocrinus epycylix, n. sp. from the Oklahoma State Highway 51 locality near Fort Gibson Lake (X 1).

strata.

The Atoka faunas consist mostly of Pennsylvanian elements, but like the Morrow fauna, include certain residual Mississippian forms.

It appears that the most reliable fossils for indicating Atokan age are the fusulinids, with certain species of Fusulinella, Profusulinella, Eoschubertella, etc., as characteristic Atokan forms. Cephalopods, with Pseudoparalegoceras williamsi, etc., also hold promise for differentiating Atokan age rocks. In addition, the brachiopod Neospirifer cameratus, is abundant in Atokan rocks.

The fossils which are dominantly controlled by facies, such as many of the brachiopods, pelecypods, and gastropods, are, of course, not as useful for stratigraphic zonation as the pelagic Foraminifera and the nektonic cephalopods.

Taonurus, previously mentioned as abundant in certain members of the Atoka formation, is a facies fossil typically associated with dirty shallow-water siltstones and fine-grained sandstones (Branson, 1954, p. 12). Although Taonurus is more abundant in Atoka siltstones and sandstones than in other Pennsylvanian rocks of eastern Oklahoma,it has been found in siltstones of the lower Desmoinesian section. The possibility exists that some Taonurus markings are swash marks, but the author currently favors the theory that most Taonurus are impressions of a seaweed. Dr. C. C. Branson collected an excellent specimen of Taonurus, which preserves a thin carbonaceous film in each of the filament impressions, from a Blackjack School siltstone in Mayes County about one mile northeast of Chouteau.

Some fossil wood and many impressions and casts of woody materials are found in many Atoka sandstones. In most instances, however, in the shelf areas of Wagoner and Mayes Counties, the same beds which contain woody material are also found to contain marine fossils. Thus, it is indicated that most of the Atoka sediments of the shelf areas are marine, and the fossil wood was rafted into the Atoka seaway from adjacent land areas.

CHAPTER VI

HISTORICAL GEOLOGY

Recent faunal evidence of the Upper Mississippian (Caney) age, of the Johns Valley shale in the Ouachita Mountains of Oklahoma, and the presence of Honess' "Morrow fauna" in the thick sandstones overlying the Johns Valley shale, has suggested the possibility that no strata belonging to the Atoka formation are present in the Ouachita Mountains, and that the uplift of the Ouachita folded belt occurred in post-Morrow, pre-Atoka time. Thin section studies of some of the Pope Chapel and Coody sandstones of the lower Atoka formation have revealed quartz grains which resemble the quartzitic grains of the Jackfork sandstone of the Ouachita Mountains, suggesting that portions of the lower Atoka sequence may have been derived, in part, from the erosion of Jackfork and other sandstones in the Ouachita folded belt.

If this concept is essentially correct, one may envision the Atokan seas in eastern Oklahoma as limited on the south by the rising folds of the Ouachita Mountains. As sediment was poured into the subsiding trough of the McAlester Basin, the Atokan sea was gradually forced northward over the northern and northeastern Oklahoma shelf areas, until it possibly extended, at one time, as far as Jasper County, Missouri. The paleographic map accompanying this paper depicts the postulated extent of Atokan seas in portions of the southwest central United States.

Evidence for the possible presence of Atokan seas in a portion of southwestern Missouri is afforded by Atokan fusulinids recovered from strata in a sink hole near Carterville, Missouri, and described by Thompson (1953, pp. 321-327).

Pre-Atoka erosion, occasioned by the uplifts of the Ouachita area to the south and the Ozark Uplift to the northeast, resulted in erosion of Morrow and Chester strata of the northeastern Oklahoma shelf. Atokan seas, advancing over the shelf area, deposited basal Atoka strata, upon Morrowan rocks in most areas, and in areas farther to the north, upon beds of the Fayetteville formation. Erosion of areas of "Boone" chert in the northeastern Oklahoma portion of the Ozark Uplift supplied chert pebbles in many areas to basal Atoka strata. Pebbles of lithographic limestone, apparently derived from Fayetteville strata, are included in the Atoka conglomerate in sec. 21, T. 25 N., R. 21 E., east of Vinita, in Craig County, Oklahoma.

As described in Chapter II, there is a progressive overlap of younger Atoka strata beyond older Atoka units northward. The quartzitic, case-hardened to friable, sandstones of the Georges Fork-Dirty Creek sequence overlap the Coody-Pope Chapel strata northward, and the Georges Fork-Dirty Creek and Webbers Falls strata are, in turn, overlapped by the upper Atoka sandstones of the Blackjack School member.

Pettijohn (1949, p. 257) suggested that the Stanley-Jackfork sequence in the Ouachita Mountains consists of typical graywacke sandstones and constitutes a pre-orogenic flysch deposit, whereas the Atoka sandstones are, in many instances, subgraywackes, and constitute a post-orogenic molasse sequence. Such a suggestion appears to agree with the proposed post-Morrow, pre-Atoka age for the Ouachita orogeny.

Early Atokan deposits to the north of the Ouachita region exhibit certain characteristics indicative of fairly rapid accumulation of a subgraywacke type of sandstone, but do not exhibit the graded bedding, high feldspar content, or extensive chloritic-clay matrix of a true graywacke. By Pope Chapel time, however, the subsiding trough had been practically filled, and the sandstones accumulated in rather shallow waters, where extensive wave winnowing occurred. As a result of these more stable conditions in the depositional site, the Pope Chapel sandstones more closely resemble the orthoquartzites of a stable shelf environment.

A measure of renewed instability of the northeastern Oklahoma shelf is indicated by the subgraywacke type sandstone of the Georges Fork-Dirty Creek sequence, but by this time the Ouachita region had been denuded, and the principal source area for sediments was the Ozark area and the cratonal land mass to the northeast and northwest, respectively.

Webbers Falls time witnessed clearing seas, with deposition of cherty siltstones and limestones and repeated influxes of black muds.

During Blackjack School time, micaceous sandstones from northern sources and ferruginous limestones of shallow water origin completed the history of Atokan deposition.

The Ouachita area supplied sediment primarily during early Atokan time. Northern source areas contributed much of the sediment during later Atokan time. In Pope Chapel time rather stable shelf conditions existed over much of the area north of the McAlester Basin.

Elsewhere in North America, the extent of Atokan seas was somewhat restricted, although Atokan strata were deposited in those areas of eastern and western North American indicated by the distribution of the Atoka equivalents mentioned in Chapter I.

General lack of coal in Atokan rocks testifies to the restriction of coal swamps, as more limited areas of the landscape were near sea level than in Desmoinesian time. However, the presence of some coal beds, the abundant scale trees, and the widespread fusulinids, probably bespeak of warming climatic conditions which were ultimately to culiminate in the mild climates which served to beget the coal swamp conditions of Desmoinesian and Allegheny time.

Faunal evidence, afforded principally by fusulinids, suggests a temporary retreat of the seas from the shelf area at the close of Atokan time, followed shortly by a re-advance of the seas in early Desmoinesian time, overlapping Atokan strata northward into Kansas.

CHAPTER VII

ATOKA SERIES

The prominent unconformity which is widespread at the base of the Atoka formation in areas of outcrop, is also somewhat in evidence in certain shelf or shallow basin portions of the subsurface, for example, the area of southwestern Kansas (Renfroe, 1954, p. 115). At the top of the Atoka formation, however, no prominent disconformity is apparent in most areas of outcrop. Thompson (1942, p. 28) discussed the fact that the Atokan Derry series of New Mexico is essentially parallel to the overlying strata of the Desmoinesian series, thus indicating that no stratigraphic break of great magnitude separates the two series. He stated, however, that faunal evidence suggests that an unconformity exists at the top of the Derry series.

No major stratigraphic break is in evidence at the top of the Atoka formation in the area under consideration in the present investigation. The unconformity, which has been suggested by faunal evidence, apparently occurs in a shale section in northeastern Oklahoma and, hence, lithologically,is essentially obscure. Fair exposures of the shale intervals at the top of the Atoka formation and the base of the Desmoinesian series are found a short distance south of Oklahoma State Highway 51 near the center of sec. 24, T. 17 N., R. 18 E., in Wagoner County, Oklahoma, approximately one mile southeast of Wagoner. Exposures of shale in a hill south of the highway are a result of partial clearing and excavating of a local area to receive the waters of Fort Gibson Lake when they are impounded to the flood control pool level. This shale slope affords no evidence of an unconformity anywhere from the top of the highest Atoka Blackjack School sandstone to the base of the escarpment-forming Warner sandstone. As has been mentioned previously, lithology, topographic expression, and position in sequence, serve to distinguish the Warner sandstone from the highest sandstones of the Blackjack School member in most places.

Spivey and Roberts (1946) pointed out that the Lampasas series, as it has been defined in Texas, does not include the Marble Falls limestone of Atokan age, but does include some strata belonging to the lower Desmoinesian section. Their proposal to elevate the Atoka to series rank appears to have been derived from fusulinid content and from evidence in the form of a pronounced basal unconformity.

The term Derryan, applied by Thompson to rocks of equivalent age in New Mexico, is often used in synonomy as a series name for lower Middle Pennsylvanian strata. The writer prefers Atokan for the series name for these strata for two reasons: (1) the Atokan section in Oklahoma is a much thicker stratigraphic section than the Derry series of New Mexico, and possibly represents a more complete record of deposition for this portion of geologic time; and (2) the Oklahoma-Arkansas area of Atoka exposure is more centrally located with respect to the Pennsylvanian sections of both eastern and western North America.

In summary, the Atokan strata are deemed to deserve series rank because of: (1) the pronounced unconformity at the base separating

Atokan strata from older rocks; (2) the evidence, supplied chiefly by fusulinids, that serves to distinguish Atokan strata from Desmoinesian rocks; (3) the general lack of coal beds in Atokan strata and the abundance of coal in Desmoinesian strata; and (4) tectonic evidence suggesting renewed orogenic movements at the end of Atokan time in portions of southern Oklahoma.

CHAPTER VIII

ECONOMIC ASPECTS OF THE ATOKA FORMATION

Atoka sandstones in the subsurface of northeastern Oklahoma are generally termed the Dutcher sands. Considerable oil production is obtained from this section, but as Weirich (1953, p. 2032) has pointed out, production is confined principally to areas north of the hinge line which existed between shelf and basin during Atokan time.

Like the Bartlesville and other Desmoinesian sands, the Atoka oil-bearing sands are rather erratic, thickening and thinning within short distances and exhibiting rapid changes in grain size and other characteristics.

Limited published information is available concerning the correlation of Atoka strata in the subsurface with the Atoka formation as exposed in the outcrop area. Wilson (1935, pp. 510-511) has presented subsurface correlations of Pennsylvanian oil and gas sands in Muskogee County, and has made the following correlative assignments for the Atoka units:

(1) the basal Coody sandstone is correlated with the Timber Ridge sand of the Muskogee County subsurface;

(2) the Pope Chapel member is correlated with the Muskogee sand;

(3) the Georges Fork member is correlated with the Bad Hole sand;

(4) the Dirty Creek sandstone is correlated with the "Gas sand";

(5) the Webbers Falls is correlated with the "Lime Marker," and

(6) the Blackjack School interval is apparently not named specifically in the subsurface.

The Coody, Pope Chapel, Georges Fork, and Dirty Creek sandstones are collectively termed the Dutcher Sands in the subsurface of Muskogee County (Wilson, 1935, pp. 510-511).

In other areas of eastern and east-central Oklahoma, the Gilcrease sands have been correlated with the Atoka formation. Local subsurface names are applied to productive units of the Dutcher and Gilcrease sands in different areas. Examples of local names include the Boynton sand of Okmulgee and Muskogee Counties; the Colbert sand of Tulsa County; the Kingwood sand of Okfuskee and Okmulgee Counties; etc.

The Moore formation of Cleveland County, Oklahoma is a unit of uncertain correlation. It was named by Wheeler in 1949 (1949, p. 156) and correlated with the Atoka formation. Objections to such correlation have been expressed by Jacobsen (1949, pp. 702-703), and discussion and rebuttal have followed (Wheeler, 1950).

Such discussion serves to point out the difficulty in attempts to recognize and correlate accurately Atokan equivalents in the subsurface of Oklahoma west of the Nemaha Ridge. East of the Nemaha Ridge, Atokan assignments may be made with a somewhat greater degree of certainty.

Weirich (1953, p. 2032) pointed out that in Creek County, Oklahoma, the Bristow and Slick fields produce from updip stratigraphic traps in the Dutcher sands, and the Depew field produces from the same sands involved in an anticlinal structure. He estimated that the Dutcher and Gilcrease sands produced 275 million barrels of oil by the end of 1950 (*ibid*.)

CHAPTER IX

SUMMARY AND CONCLUSIONS

The Atoka formation of the shelf area of northeastern Oklahoma is a lithologic complex characterized by intricate facies changes as a result of multiple source areas and varying degrees of tectonic behavior in source areas and depositional sites.

Three major source areas are evidenced: the Ouachita Mountain area of southeastern Oklahoma and southwest central Arkansas; the Ozark Uplift in northeastern Oklahoma, northwestern Arkansas, and southern Missouri; and the cratonal area to the north and northwest in northern Oklahoma and Kansas.

The Atoka units of the McAlester Basin area include great accumulations of shale and are believed to constitute a molasse type deposit from the Ouachita area. Much of the thinner portions of the shelf section of the Atoka formation involve sediments derived from the Ozark Uplift to the east and the cratonal shores to the north.

Many lower and middle Atoka sandstones are subgraywackes, although the Pope Chapel sandstone of the shelf area exhibits a greater degree of sorting and a closer approach to a shelf type "blanket" sand than do other Atoka units. Georges Fork-Dirty Creek sandstones are subgraywackes which accumulated on a somewhat unstable shelf area. The Webbers Falls member attests to clearing seas and a low-lying source area. The uppermost Atoka unit, or Blackjack School member, is a micaceous sandstone deposited in the Atoka seas during their maximum northward extent. The progressive northward advance of Atoka seas is evidenced by the overlap northward of younger Atoka units beyond older members.

A prominent disconformity at the base of Atoka strata is believed to correlate in time with the Wichita orogeny of southern and southwestern Oklahoma, and the Ouachita orogeny of southeastern Oklahoma. A time break at the top of the Atoka section is not readily apparent in the field, but may be inferred from faunal evidence.

The most significant faunal elements for identifying Atoka strata are fusulinids, with certain species of Fusulinella, Fusiella, Profusulinella, Eoschubertella, and Pseudostaffella indicative of Atokan age. Cephalopods, such as Pseudoparalegoceras williamsi, and other forms, hold promise as Atokan age delineators.

The Atoka formation includes numerous oil-producing sands, known as Dutcher and Gilcrease, in the subsurface of eastern and east-central Oklahoma. These sands are markedly lenticular, so that localized and highly variable production characterizes areas of Atoka fields.

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APPENDIX A

COMPOSITE SECTION OF THE ATOKA FORMATION ON BRUSHY MOUNTAIN,

SECTIONS 4 & 5, T. 13 N., R. 25 E.,

SEQUOYAH COUNTY, OKLAHOMA

(Measured from the Atoka-Morrow contact in Akins Hollow to the top of Brushy Mountain and also from the Greasy Creek fault along U. S. Highway 59 to the top of Brushy Mountain.)

23.6 ft. Covered to top of hill.

4.5 ft. Sandstone, white to buff; fine-grained; friable; slightly cross-bedded; fairly massive; subangular grains.

76.8 ft. Covered.

8.7 ft. Sandstone, pink to buff; fine-grained; massive; micaceous.

17.1 ft. Covered.

5.0 ft. Sandstone, buff to pink; weathers buff to dark grayish-brown or reddish-brown; medium-grained; friable; moss covered; relatively clean sand, with subangular grains.

1.0 ft. Sandstone, reddish-brown; ferruginous; porous; weathers cinder-like; numerous fossil molds of crinoid columnals, brachiopods, etc.

11.1 ft. Covered.

8.0 ft. Sandstone, olive-brown to reddish; fine-grained; concretionary.

45.6 ft. Sandstone, buff to gray; fine-grained; thin-bedded; some ripple marks; weathers white to light rusty buff; micaceous. Some thin interbedded, dark gray, micaceous shales. Some woody fragments. The upper 6 to 7 feet include fine-grained sandstone, white; weathers tan; contains molds of crinoid columnals.

3.6 ft.	Sandstone, silvery to copper gray; fine-grained; micaceous; non-calcareous; fucoidal.
6.7 ft.	Shale, black; weathers fissile; clay-ironstone concretions.
5.7 ft.	Siltstone, light gray to dark gray, with ironstone concretions. Some fine-grained, micaceous, shaly sandstones which weather sooty gray.
0.3 ft.	Shale, black; fissile.
2.2 ft.	Siltstone, gray; weathers light gray; rusty stained; micaceous; mud cracks.
5.5 ft.	Covered.
3.3 ft.	Sandstone, grayish-buff to gray; fine-grained; calcareous. Crinoid columnals and other fossil fragments. Upper 1.5 ft. non-calcareous and has ironstone concretions.
11.9 ft.	Sandstones, gray to buff; weather very light buff; very fine-grained; siltstones, gray to buff. Ironstone concretions. Both sandstones and siltstones are thin, micaceous, with ripple-marked bedding. Pelecypod and brachiopod fragments and molds.
6.7 ft.	Sandstone, frosty gray to pinkish gray to buff; thin-bedded; fine-grained; non-calcareous.
5.4 ft.	Sandstone, light gray to buff; weathers dirty grayish to buff; very fine-grained; thin uneven bedded; non-calcareous.
9.7 ft.	Siltstone, light gray to buff, with interbedded concretionary zones. Small limonitic siltstone concretions.
2.0 ft.	Shales and siltstones, gray, with ironstone concretions.
3.5 ft.	Shale, gray to black; splintery.
10.6 ft.	Covered.
5.1 ft.	Siltstone, light gray to buff; weathers dirty grayish to tan; micaceous.
0.5 ft.	Sandstone, dark olive brown with reddish stains. Very fine-grained.
28.4 ft.	Sandstones and siltstones, gray to light purplish-buff; weather light gray to buff; relatively thin-bedded, concretionary, with large, hollow ironstone concretions. Dark purplish-brown crusts along joint planes.

6.7 ft.	Siltstone and silty shale, gray to light purplish-buff; weathers rusty gray-brown; non-calcareous; micaceous; some portions weather chalky. Fucoidal.
7.6 ft.	Shale, black; weathers dark gray to gray; fissile; clay-ironstone beds.
57.7 ft.	Covered.
61.8 ft.	Sandstone, light gray, with uneven black stringers and streaks of carbonaceous matter. Weathers olive buff. The more massive middle 15 ft. portion exhibits cavernous to honeycomb weathering.
31.8 ft.	Covered.
8.9 ft.	Calcarenite, massive.
16.8 ft.	Covered.
1.7 ft.	Calcarenite, with normal cross-bedding; reddish-gray; contains many crinoid stems and brachiopod fragments. Ferruginous cementing material.
2.3 ft.	Basal conglomerate, reddish-brown; ferruginous and calcareous cementing material; calcareous pebbles, approximately 1 inch by 0.75 inch in size. Bed varies in thickness from 1.5 ft. to 5.3 ft. within 20 yards of exposure along stream in Akins Hollow. Numerous small clay ironstone pebbles or concretions. (This unit constitutes the base of the Atoka formation.)

507.8 ft. = Total measured thickness of Atoka formation.

APPENDIX B

MEASURED SECTION OF THE ATOKA FORMATION NEAR TENKILLER DAM, SECTIONS 14 and 23, T. 13 N., R. 21 E., SEQUOYAH COUNTY, OKLAHOMA

102.6 ft.	Covered to top of hill. Slump blocks of sandstone, pink to brown, with brown limonitic specks, and dark olive brown, fine-grained, quartzitic. These sandstones are typical of the Georges Fork-Dirty Creek facies.
10.6 ft.	Sandstone, light buff, fine-grained, non-calcareous.
1.3 ft.	Sandstone, white to orange buff; fine-grained; porous; with many fossil molds; grades laterally into calcarenite, light gray to buff, with many crinoid fragments.
0.3 ft.	Sandstone, dark rusty brown; weathers dark dirty gray; fine-grained; limonitic; porous; some fossil molds.
48.7 ft.	Sandstone, buff to gray; very fine-grained; carbonaceous streaks.
5.5 ft.	Covered. Slump block of sandstone, light olive gray, with carbonaceous streaks; fine-grained; non-calcareous.
4.9 ft.	Sandstone, buff; weathers rusty reddish-brown; fine-grained; small chert fragments. Beds approximately 0.4 ft. thick.
3.4 ft.	Sandstone, buff; weathers dirty gray; fine-grained; black carbonaceous streaks; non-calcareous.
4.0 ft.	Sandstone, light tan; weathers dark reddish-brown to brown; fine-grained; non-calcareous; black, carbonaceous streaks. Bedding approximately 0.8 ft. thick.
8.2 ft.	Sandstone, light buff to gray; very fine-grained; weathers to yield an uneven surface, raspy to the touch; streaks and stringers of carbonaceous matter; concretionary.

17.1 ft.	Sandstone, buff; weathers light gray to rusty grayish-brown; very fine-grained; slightly micaceous; faint carbonaceous streaks; dense; non-calcareous. (Certain zones to the north are shaly, and weather cavernous or with honeycomb structure; carbonaceous streaks prominent in the softer shaly zones.)
9.6 ft.	Covered.
2.8 ft.	Sandstone, rusty buff; medium-grained; porous; non-calcareous; contains crinoid fragments.
4.2 ft.	Calcarenite, gray; limonitic specks and streaks; upper 1.6 ft. thin bedded.
0.3 ft.	Sandstone, light gray to white; weathers dirty gray; irregular carbonaceous streaks; calcareous; contains small crinoid fragments.
1.0 ft.	Sandstone, light olive buff; weathers dirty grayish-buff; fine-grained; calcareous; scattered crinoid fragments; individual beds approximately 0.2 ft. thick.
3.6 ft.	Calcarenite, grayish-tan; weathers dirty gray and sandy; limonitic; quartz grains large and scattered; many crinoid fragments.
1.3 ft.	Sandstone, rusty brown; weathers dirty gray to white; fine-grained; friable.
1.2 ft.	Sandstone, light olive buff; calcareous; large limonitic specks; thin-bedded.
1.5 ft.	Sandstone, light olive buff; weathers dirty gray; fine-grained; tiny limonitic specks; porous.
10.0 ft.	Covered.
1.6 ft.	Sandstone, olive gray; weathers light olive gray to rusty brown; fine-grained; slight calcareous content; black carbonaceous streaks.
9.8 ft.	Sandstone, light buff; weathers dark grayish-brown; fine-grained; calcareous; fairly massive.
1.1 ft.	Sandstone, light gray; fine-grained; calcareous;irregular carbonaceous streaks. Less resistant to weathering than the adjacent rocks; forms re-entrant level in cliff.
1.7 ft.	Sandstone, buff; fine-grained; calcareous; riddled with *Scolithus*-like tubes.

3.0 ft. Sandstone, white to light gray; medium-grained; slightly calcareous; weathers cavernous; contains small pods of light gray clay approximately 0.5 inch long and 0.23 inch thick. Grades upward into limestone, gray, sandy, finely crystalline.

10.3 ft. Sandstone, light olive buff; weathers light purplish-brown; medium-grained; massive. Grains somewhat ovoid, apparently due to accretion or secondary enlargement. (This unit constitutes the base of the Atoka formation.)

269.6 ft. = Total measured thickness of the Atoka formation.

APPENDIX C

MEASURED SECTION OF ATOKA FORMATION ALONG THE ROAD LEADING SOUTH UP THE HILL FROM THE EAST END OF FORT GIBSON DAM. EAST ½ SEC. 18, T. 16 N., R. 19 E., CHEROKEE COUNTY, OKLAHOMA

1.5 ft.	Sandstone and conglomeratic sandstone, reddish-brown, hematitic-stained; coarse-grained to conglomeratic; many woody fragments, Lepidodendron impressions, etc. (Top of hill.)
4.2 ft.	Sandstone, reddish-brown, thin-bedded.
1.1 ft.	Conglomerate, with small chert pebbles.
2.3 ft.	Covered.
33.3 ft.	Siltstone, olive-tan with thin black streaks; thin-bedded to massive. Manganese oxide stains abundant. Ironstone concretionary structures in the lower and upper portions of the interval.
4.4 ft.	Sandstone, grayish-brown; fine-grained; thin-bedded, with ripple marks.
6.4 ft.	Covered.
1.0 ft.	Sandstone, rusty brown; fine- to medium-grained; fairly massive; streaked with manganese oxide stains.
0.6 ft.	Sandstone, rusty brown; weathers dirty grayish brown; fine-grained; thin-bedded.
0.6 ft.	Sandstone, dirty yellow brown with abundant black specks and streaks; fine-grained.
5.0 ft.	Sandstones and claystones interbedded, rusty red; thin. Sandstones are fine-grained with subrounded quartz grains.

5.5 ft. Covered.

1.5 ft. Sandstone, dirty yellow brown to dark brown with thin black streaks; fine-grained; thin platy bedding.

1.2 ft. Sandstone, rusty to olive-drab; weathers greenish-gray; fine-grained; fairly massive; abundant manganese oxide stains.

9.5 ft. Covered.

1.0 ft. Sandstone, light olive brown; weather dirty brown; fine-grained; unevenly cross-bedded; abundant manganese oxide stains.

3.0 ft. Covered.

0.8 ft. Sandstone, dirty brown with limonitic specks; fine-grained; some clay pellets.

15.0 ft. Covered.

0.4 ft. Sandstone, reddish tan with scattered limonitic specks; fine-grained; resistant.

1.2 ft. Sandstone, buff to rusty tan; fine-grained; subrounded quartz grains; thin bedded, with ripple marks.

0.8 ft. Sandstone, yellow brown with purplish specks and limonitic streaks; fine-grained.

1.9 ft. Sandstone, buff to tan; weathers dark brown; medium-grained; well-rounded quartz grains.

1.6 ft. Sandstone, buff to reddish tan; weathers rusty red; medium-grained; subrounded quartz grains; resistant.

2.3 ft. Sandstone, light brown with black streaks and limonitic stains; fine-grained; thin-bedded.

1.6 ft. Sandstone, brown with limonitic banding; fine-grained.

1.5 ft. Sandstone, light brown; very fine-grained; thin bedded; slightly calcareous.

2.8 ft. Sandstone, tan with abundant black streaks; very fine-grained; thin-bedded.

0.3 ft. Sandstone, tan; very fine-grained; mice flakes; thin-bedded.

0.3 ft. Clay-ironstone concretions.

0.2 ft. Shale, gray.

1.1 ft. Sandstone, dirty brown to brownish gray; fine-grained.

0.9 ft. Sandstone, light gray; fine-grained; scattered mica flakes; platy-bedded.

1.6 ft. Sandstone, brown; fine-grained; black streaks.

1.2 ft. Shale, light gray; weathers brownish gray.

3.6 ft. Sandstone, brownish gray; thin-bedded; limonitic concretions.

2.7 ft. Sandstone, light gray, with tiny iron oxide specks; weathers tan to light pinkish brown; fine-grained; calcareous.

6.7 ft. Shale, black, with interbedded sandstones and ironstone concretions. Concretions larger and more abundant in the upper 0.8 ft. Upper shale is splintery to shaly, with reddish-brown to light yellow stains; lower shale is subfissile and dark gray to black.

3.8 ft. Sandstone, gray to buff; fine-grained; massive; calcareous. Upper portion cross-bedded and only slightly calcareous.

0.5 ft. Sandstone, buff; fine-grained; slightly calcareous.

11.6 ft. Sandstone, gray to buff, with black carbonaceous streaks and stringers; fine-grained.

0.4 ft. Shale, gray, with sulfur-yellow and greenish-brown stains in weathered portions; splintery.

2.8 ft. Sandstone, light gray to buff with carbonaceous stringers; fine-grained; slightly calcareous.

2.3 ft. Sandstone, lensing and interbedded with shaly, carbonaceous, fine-grained sandstones.

0.5 ft. Shale, black, sub-fissile; numerous fucoids.

2.5 ft. Sandstone, light gray; fine-grained; shaly; calcareous. Middle portion more sandy; upper 0.5 ft. more shaly. Lower surface possesses fucoid-like, rounded ridges and mounds.

1.1 ft. Shale, grayish black to black. Lower 0.5 ft. is sandy carbonaceous shale with uneven bedding; weathers light dirty-buff to light gray. Fresh surfaces are grayish-black, with a peculiar greasy to coaly luster. Upper portion is black, with paper-thin bedding. Pellet-like objects in upper portion appear phosphatic.

3.1 ft. Sandstone, buff to gray to maroon. Lower 0.5 ft. is buff, fine-grained, calcareous, with small rusty brown limonitic specks. Middle 1.3 ft. is gray to light gray, very fine-grained, highly calcareous. Upper portion is maroon and white, speckled, fine-grained.

0.1 ft. Shale, black, fissile.

7.2 ft. Sandstone, tan to dirty brown; fine- to medium- grained. Basal portion is slightly conglomeratic, with clay pebbles. Basal 2.3 ft. cross-bedded. Upper portions fine-grained. Small "fraction-of-an-inch" shale breaks occur in upper 2 feet. (This unit constitutes the base of the Atoka formation.)

166.5 ft. = Total measured thickness of Atoka formation.

APPENDIX D

MEASURED SECTION OF ATOKA FORMATION ALONG ROAD LEADING SOUTHWESTWARD AND WESTWARD FROM FORT GIBSON DAM, THROUGH SECTIONS 13, 14, 23, 22, 15 and 16, T. 16 N., R. 19 E., WAGONER COUNTY, OKLAHOMA

53.8 ft.	Covered to top of hill, SE¼ sec. 16, T. 16 N., R. 19 E. Apparently this interval consists of Webbers Falls siltstones.
5.6 ft.	Siltstones, buff. (Northwest corner sec. 22, T. 16 N., R. 19 E. Dip 12½° NW.)
1.3 ft.	Limestone, light gray; slightly cavernous.
2.2 ft.	Shale, dark gray; calcareous, with large limestone nodules in the upper 0.5 ft.
12.0 ft.	Siltstone, buff, porous; light weight; carbonaceous streaks. Horizontal fractures. Dip 8° S 38° E.
26.3 ft.	Covered.
4.2 ft.	Siltstone, buff; porous; light weight. Well-developed horizontal and vertical fractures. (NW¼ NW¼ sec. 23, T. 16 N., R. 19 E.)
17.8 ft.	Covered. Within this interval are slump blocks and occasional thin exposures of Webbers Falls siltstone and ferruginous limestone.
0.3 ft.	Siltstone, buff, with cavities lined with limonitic clay. Carbonaceous streaks.
5.3 ft.	Covered.
2.5 ft.	Limestone, dark gray; shaly; thin-bedded.
2.2 ft.	Covered. Probably shale.

1.0 ft.	Limestone, grayish buff to reddish tan; weathers buff; shaly bedding; contains brachiopods and crinoid columnals.
1.3 ft.	Sandstone, dull olive drab; fine-grained; calcareous; uneven bedded; fucoid-marked.
8.5 ft.	Siltstones and shales, gray to buff, thin-bedded.
7.1 ft.	Limestone, dark gray; argillaceous; thin shaly bedding. NW¼ NE¼ sec. 23, T. 16 N., R. 19 E.
4.0 ft.	Sandstone, light gray; weathers buff; *Taonurus* markings.
24.3 ft.	Covered. Probably A_4 shale interval. Mantled with Webbers Falls slump from hill to the west.
38.1 ft.	Sandstone, pinkish tan to buff to gray; weathers reddish brown; medium grained; friable. Much of this interval is covered. Approximately 15 ft. above base are molds of brachiopods. Massive, friable, buff sandstone appears to be present in the interval from 20 ft. above the base to about 31 ft. above the base. About 7 ft. below the top are buff, slightly conglomeratic sandstones, friable, medium- to coarse-grained, with many brachiopod molds. (SE¼ NW¼ sec. 13, T. 16 N., R. 19 E.)
3.6 ft.	Sandstone, pink to dirty grayish brown; speckled; contains red ocherous clay lenses or pods; some plant stems preserved in black iron- or manganese- oxide impressions; grains subangular.
20.0 ft.	Covered.
11.1 ft.	Siltstone, gray to olive gray; weathers buff; micaceous to argillaceous.
1.3 ft.	Sandstone, olive drab; weathers reddish brown and cinder-like; fine- to medium-grained.
0.6 ft.	Clay, olive drab to reddish brown; silty; rubbly-weathering.
1.9 ft.	Sandstone, olive drab; weathers dark brown; fine- to medium-grained, with limonitic cement and splotches.
1.0 ft.	Clay-ironstone and sandstone, yellow brown; thin; ripple-marked bedding.
52.5 ft.	Covered.
0.8 ft.	Sandstone, light olive buff to light greenish gray; fine-grained; fucoidal; some limonitic cement.

0.5 ft.	Sandstone and clay ironstone, reddish-brown; thin; shaly appearance; ripple-marked bedding.
4.2 ft.	Sandstone, olive drab; weathers buff; interbedded with clay shales, dark gray. Sandstones are ripple-marked, quartzose, with some fucoids.
2.4 ft.	Limestone, reddish-brown, ferruginous, with numerous spiriferoid brachiopods, crinoid columnals, and large chert and chalcedonic sand grains. Upper 0.7 ft. is cross-bedded. Top 0.3 ft. has cinder-like appearance.
23.9 ft.	Sandstone, buff to olive gray to khaki-colored; weathers very light gray; grains appear well-rounded; fairly massive; non-calcareous.
2.7 ft.	Shale, gray to buff; silty; micaceous; thick carbonaceous streaks.
11.8 ft.	Sandstone, light buff, speckled; fine-grained; calcareous in part.
14.3 ft.	Covered. Interval appears to include sandstone, rusty tan to speckled, fine-grained, fairly massive; and shale, black, with clay-ironstone concretions. One sandstone near top of this interval bears fucoid markings.
0.5 ft.	Conglomerate, reddish-brown, ferruginous; contains limestone pebbles and abraded fossil fragments derived from underlying Morrow group. Contact with Morrow is, in part, gradational. (This unit constitutes the base of the Atoka formation.)

370.9 ft = Total measured thickness of Atoka formation.

APPENDIX E

MEASURED SECTION OF A PORTION OF THE WEBBERS FALLS MEMBER OF THE ATOKA FORMATION, EXPOSED IN A CLIFF ON THE EAST WALL OF THE VALLEY OF THE VERDIGRIS RIVER, WEST ½ SW¼ SEC. 29, T. 16 N., R. 19 E., WAGONER COUNTY, OKLAHOMA.

27.0 ft. Covered to the top of the hill. This interval probably includes a portion of the Blackjack School sandstone member of the Atoka formation.

7.4 ft. Siltstone, buff, slightly calcareous, massive, leached, with core limestone. Solution holes are small. Core limestone is grayish buff and finely crystalline.

3.3 ft. Siltstone, buff, cherty, with thin black carbonaceous streaks and stringers.

0.2 ft. Siltstone, light gray; cherty. Several thin irregular layers.

0.2 ft. Chert, gray.

5.2 ft. Limestone, gray; finely crystalline.

2.5 ft. Siltstone, light gray; dense; calcareous; carbonaceous streaks.

Base not exposed.

45.8 ft = Total measured thickness of Webbers Falls member of the Atoka formation. Upper 27 feet possibly includes a portion of the overlying Blackjack School member.

APPENDIX F

COMPOSITE SECTION OF THE ATOKA FORMATION, MEASURED IN SECTIONS 1, 2, AND 12, T. 17 N., R. 20 E., CHEROKEE COUNTY, OKLAHOMA.

(The section was measured partially on the southern, or upthrown, side and partially on the northern, or downthrown, side of an east-westward trending fault which follows the valley of Fourteen Mile Creek, approximately ½ mile south of Lost City, Oklahoma.)

26.3 ft.	Covered to the approximate top of the Atoka section.
1.0 ft.	Sandstone, light gray, with limonitic specks; fine-grained; thin; ripple-marked bedding.
1.1 ft.	Clay shale, light gray to light buff; somewhat micaceous; beds approximately 1 cm thick.
12.2 ft.	Covered.
2.2 ft.	Siltstone, gray; weathers dirty gray buff to rusty yellow brown; calcareous; platy; *Taonurus* markings. Dip 13°, N 42° W.
3.4 ft.	Siltstone, dark gray; shaly.
3.8 ft.	Siltstone, dark gray; slabby to platy.
4.0 ft.	Covered.
12.0 ft.	Limestone, light gray to light gray buff; fine- to medium-crystalline. In places, a porous, buff siltstone is associated with the limestone in intimately enveloping and interpenetrating relationships. This interval is believed to be part of the Webbers Falls member of the Atoka formation. Dip is 9° to 11° north. Bed of Fourteen Mile Creek occupies a portion of the zone of drag of the east-westward trending fault.

The preceding units were measured on the downthrown side of the fault in the valley of Fourteen Mile Creek. The following units were measured on the upthrown side of the fault on the hill south of Fourteen Mile Creek.

26.9 ft. Sandstone, buff- to olive brown; weathers dark brown; fine-grained; case-hardened appearance on weathered surfaces. Some units exhibit Taonurus markings; some units show reddish and light olive buff, thin, irregular streaks, resembling cobwebs; certain units are slightly conglomeratic. Interval is largely covered but has many detached slump blocks to the top of the hill. Typical Georges Fork-Dirty Creek lithology.

5.1 ft. Covered.

0.8 ft. Sandstone, white, with tiny limonitic specks to buff; weathers reddish tan; fine-grained; fucoidal markings. Numerous cavities are lined with loosely-cemented sand grains.

5.3 ft. Covered.

2.5 ft. Limestone, rusty brown to grayish brown; and sandstone, olive drab. Limestone is medium crystalline, with numerous brachiopods; sandstone fine-grained, with clay stringers, and contains certain calcareous centers and areas containing fossil brachiopods. Lower portion of sandstone is dark brown, with olive to rusty clay pods.

3.5 ft. Siltstone, light olive grayish buff; weathers dull grayish buff to dirty grayish buff; faint cross bedding and thin laminations shown by lines of slight color differences; thin; irregular bedding.

8.8 ft. Covered.

0.7 ft. Sandstone, rusty brown to tan, with fine limonitic specks; weathers dirty brown; fine-grained; small olive-green clay pods and stringers; concentric concretionary markings.

2.3 ft. Covered. Probably shale.

0.4 ft. Sandstone, olive drab; very fine grained; dense; quartzitic appearance. Some reddish-orange stains and fucoid markings.

2.8 to 4.2 ft. Sandstone, rusty olive-brown to olive drab to rusty brown; fine-grained; porous,due to many fossil molds; beds approximately 0.25-0.5 ft. thick and are irregular; contain some olive clay lenses. Within a few yards laterally, the section thickens to 4.2 ft., and the middle portion is limy, and in part, consists of limestone, gray to rusty, and finely crystalline. Some thin clay lenses.

10.5 ft. Covered; probably shale. Some shale and shaly siltstone is exposed within the interval. Shale is dark gray and weathers light grayish tan to gray; it is slightly silty and is fissile to sub-fissile. Slump blocks of sandstone, light olive buff, fine-grained, are present in this interval. The sandstone is relatively porous due to many fossil molds. This interval constitutes the base of the Atoka formation and rests disconformably upon the underlying Morrow limestone.

137.0 ft. = Total measured thickness of the Atoka formation.

APPENDIX G

MEASURED SECTION OF THE ATOKA FORMATION IN WOODS APPROXIMATELY 300 YARDS NORTH OF THE EAST END OF THE OKLAHOMA STATE HIGHWAY 51 BRIDGE OVER FORT GIBSON LAKE.

SE¼ SEC. 22, T. 17 N., R. 19 E.,

CHEROKEE COUNTY, OKLAHOMA

30.9 ft.	Covered to top of hill.
1.1 ft.	Sandstone, buff to brown; fine-grained; ripple-marked bedding; quartzitic appearance. Non-calcareous.
2.5 ft.	Limestone, white to buff to gray; thin-bedded.
2.4 ft.	Sandstone, buff to grayish buff; fine-grained; non-calcareous. Finer-grained toward top. Dark brown, lichen-coated, weathered surfaces.
2.2 ft.	Sandstone, rusty; medium-grained; limonitic cement.
10.3 ft.	Covered.
3.5 ft.	Sandstone, dirty buff with limonitic blotches; fine- to medium-grained; calcareous. Certain quartz grains appear to be secondarily enlarged. Orbiculoidea-type brachiopod and other fossil fragments. Lower 1 ft. less calcareous than upper 2.5 ft.
3.6 ft.	Siltstone, gray; platy; calcareous; fucoid markings.
2.9 ft.	Covered.
3.0 ft.	Sandstone, buff; medium- to coarse-grained to conglomeratic; calcareous; limonitic specks; impressions of wood; some brachiopod fragments.
8.4 ft.	Covered.

7.4 ft.	Sandstone, gray to buff; medium-grained; calcareous; thin-bedded. Contains woody fragments and brachiopod remains.
2.4 ft.	Calcarenite, gray; coarse-grained.
1.1 ft.	Sandstone, rusty grayish brown; coarse-grained to locally conglomeratic.
1.1 ft.	Sandstone, rusty brown to buff; medium-grained. Lower portion thinner bedded and more calcareous than upper portion.
1.2 ft.	Sandstone, white to buff, with limonitic specks; fine- to medium-grained; calcite cement.
4.2 ft.	Sandstone, rusty tan; fine- to medium-grained; ripple-marked bedding; much limonitic cement.
2.5 ft.	Sandstone, gray to rusty buff; medium-grained; fairly massive; calcite cement.
0.8 ft.	Conglomerate, rusty to reddish-brown, with flattened pebbles of clay and limestone up to 3.5 inches to 4 inches in length. Large amounts of calcite cement in lower part. Contains brachiopod and crinoid stem fragments. This is the basal unit of the Atoka formation.

91.5 ft. = Total measured thickness of the Atoka formation.

APPENDIX H

MEASURED SECTION OF THE ATOKA FORMATION FROM THE WAGONER PUMPING STATION (SW¼ SW¼ NW¼ SEC. 20, T. 18 N., R. 19 E.) WEST TO U. S. HIGHWAY 69, WAGONER COUNTY, OKLAHOMA.

16.0 ft.	Covered to base of overlying Warner sandstone.
4.0 ft.	Shale, dark gray, with calcareous nodules. A 1 ft. bed of dark gray, finely crystalline limestone grades laterally into the gray shale with calcareous nodules.
3.5 ft.	Covered.
3.5 ft.	Sandstone, olive brown; fine-grained; thin-bedded.
9.6 ft.	Covered.
8.2 ft.	Shale, dark gray, with calcareous nodules. Nodules are dark gray calcilutites which weather white to light buff.
7.0 ft.	Covered.
55.5 ft.	Sandstone, buff; medium-grained; locally cross-bedded; weathers brown; numerous fossil molds.
5.0 ft.	Shale, dark gray, with calcareous nodules. Nodules are dark gray calcilutites which weather white to light buff.
27.0 ft.	Covered.
1.0 ft.	Sandstone, rusty; medium-grained.
3.7 ft.	Covered.
8.8 ft.	Sandstone, buff; weathers brown, with smooth, case-hardened surfaces; fine-grained.
1.9 ft.	Covered.

0.5 ft.	Sandstone, white to buff; medium-grained; limonitic specks, splotches, and streaks.
5.4 ft.	Covered.
0.5 ft.	Siltstone, buff; porous; light weight; some small chert fragments and manganese oxide stains.
19.2 ft.	Shale, dark gray, with thin nodular calcilutites. Partly covered.
0.4 ft.	Calcilutite, dark gray; weathers light buff. Joint pattern and weathering results in separation into cobbles.
3.0 ft.	Siltstone, dirty grayish buff; calcareous; prominent <u>Taonurus</u> markings and crinoid columnals.
20.9 ft.	Shale, black; fissile. Mostly covered.
1.0 ft.	Limestone, gray; medium-crystalline; contains molds of brachiopods and pectinoid pelecypods.
25.1 ft.	Shale, black; fissile. Mostly covered.
17.0 ft.	Conglomerate, rusty brown, with subrounded chert pebbles. Pebbles average approximately 0.7 inch in diameter. Large red ocherous clay pods at the base. <u>Pleurodictyum</u> and crinoid columnals. This unit constitutes the base of the Atoka formation.

247.7 ft. = Total measured thickness of the Atoka formation.

APPENDIX I

MEASURED SECTION OF THE ATOKA FORMATION ALONG THE MAYES-WAGONER COUNTY LINE ROAD, BETWEEN SECTIONS 4 AND 5, T. 18 N., R. 19 E. AND SECTIONS 32 AND 33, T. 19 N., R. 19 E., OKLAHOMA

12.1 ft. Sandstone, rusty brown; conglomeratic, with chert fragments and clay particles. Portions of this interval have a cinder-like appearance. Slightly fossiliferous. (Blackjack School sandstone.) Caps top of hill.

3.2 ft. Covered. (A_5 shale.)

0.8 ft. Limestone, light gray to rusty tan; fine- to medium-crystalline; massive.

3.4 ft. Siltstone, vesicular, with core limestone. Siltstone, light buff to cream-colored; weathers dark grayish brown in places. Vesicles are irregularly circular to pod-shaped. Siltstone coloration laminae bend around pods. In less weathered zones, where leaching has not yet formed holes, pods of finely crystalline,gray to light tan,core limestone are present. This limestone probably occupied the sites of all the vesicles before leaching. Holes and vesicles contain a rusty, "gossan"-type residue in many instances. The core limestone is exposed within the middle portion of the siltstone section and lenses into vesicular siltstone at both extremities of its 3-foot length of exposure. Maximum thickness of core limestone exposed is about 0.4 ft. It is fine- to medium-crystalline, light grayish tan to light gray, with some glauconite, and is slightly fossiliferous. On the north side of the road, a greater thickness of core limestone is exposed in one place, and has a vesicular siltstone envelope.

1.6 ft. Limestone, light gray; weathers buff and shaly to rusty reddish-brown; finely crystalline; a few brachiopods.

0.6 ft. Covered.

0.6 ft. Limestone, gray to grayish tan; finely crystalline; shale streaks.

0.6 ft. Shale, light gray; sub-fissile; silty; crumbly; non-calcareous.

0.4 ft. Limestone, gray to grayish tan to light grayish brown; finely crystalline; carbonaceous streaks. Weathers light gray to buff, with a sandy surface. (This unit constitutes the base of the Webbers Falls member.)

0.3 ft. Shale, rusty brown to buff to light gray; crumbly.

4.3 ft. Covered. (A_4 shale)

2.0 ft. Sandstone, rusty to olive drab; fine-grained; dull luster; somewhat crumbly. A few grains are larger and more gritty than the majority, and some small chert particles are present. (This bed is at the top of the Georges Fork-Dirty Creek sequence.)

14.4 ft. Covered. Many scattered slump blocks of sandstone, light buff, fine-grained, friable to quartzitic, with dark brown, smooth, case-hardened weathered surfaces and abundant fucoids and Taonurus. On many slump blocks an outer weathered zone, about one centimeter or more in thickness, is dark brown in color, and is more quartzitic than the buff interior. One of the beds is massive, 1.8 ft. thick. Another is olive drab, fine-grained, quartzitic, with clay streaks, 0.4 ft. thick. (This interval is included in the Georges Fork-Dirty Creek sequence.)

0.6 ft. Sandstone, buff; fine-grained; reddish stains and abundant Taonurus markings. This appears to be the basal unit of the Georges Fork-Dirty Creek sequence.

51.5 ft. Covered. Upper portion contains clay shales, gray to light rusty yellow, and thin sandstones, white, fine-grained.

20.2 ft. Sandstone, pink; medium- to coarse-grained; gritty and conglomeratic; somewhat friable. Contains large chalcedonic sand grains and decayed chert grains; woody impressions numerous.

2.3 ft. Covered.

2.0 ft. Sandstone, speckled to rusty brown; weathers pinkish buff; fine- to medium-grained; friable; many fossil molds.

2.0 ft. Covered with sand, rusty red, fine-grained.

0.4 ft. Sandstone, rusty; weathers pinkish buff; fine-grained; friable.

0.7 ft. Covered with sand, rusty red, fine-grained.

0.7 ft. Sandstone, rusty buff, with white specks of decayed chert; fine- to medium-grained; surface marked by crenulated depressions resembling worm borings.

0.5 ft. Sandstone, white, with limonitic specks; weathers pinkish buff; fine- to medium-grained; thin-bedded; slightly friable; numerous fossil molds.

0.7 ft. Covered.

1.9 ft. Sandstone, white, with limonitic specks; weathers pinkish buff; fine- to medium-grained; massive.

0.3 ft. Sandstone, grayish buff; weathers pinkish buff; calcareous; fine-grained.

1.0 ft. Sandstone, rusty; weathers pinkish buff; fine- to medium-grained; clear quartz grains, loosely cemented with limonitic cement; crumbles readily under hammer blows.

3.0 ft. Covered. Probably sandstone. Interval rests disconformably upon Morrow limestone.

132.1 ft. = Total measured thickness of Atoka formation.

APPENDIX J

MEASURED SECTION OF THE ATOKA FORMATION,

NE¼ SEC. 34, T. 19 N., R. 19 E.,

MAYES COUNTY, OKLAHOMA

17.7 ft.	Covered to top of ridge. Georges Fork-Dirty Creek sandstones.
5.0 ft.	Sandstone, buff to pinkish buff; weathers gray; medium- to fine-grained; sub-angular; friable; porous; non-calcareous; medium-bedded. Blocks covered with lichens and moss.
38.6 ft.	Covered. Slump blocks of Dirty Creek sandstone, gray to buff, with Taonurus markings.
16.6 ft.	Limestone, light gray to greenish gray; weathers greenish gray; medium- to coarsely crystalline.
3.6 ft.	Limestone, gray; weathers dirty gray; dense, slightly fossiliferous; a tendency toward birdseye texture.
2.3 ft.	Calcarenite, light grayish buff to yellowish tan; very fine oolitic-type grains.
6.6 ft.	Covered.
6.5 ft.	Limestone, grayish buff; weathers dirty gray; fine- to medium-crystalline; thin-bedded; fenestellid bryozoans, crinoid columnals, and brachiopod fragments.
11.5 ft.	Covered.
1.6 ft.	Sandstone, olive buff; calcareous; fine-grained; thin-bedded. Crinoid and brachiopod fragments.
4.7 ft.	Calcarenite, grayish buff; medium to finely crystalline; more massive than unit immediately below. Numerous fossils.
2.5 ft.	Calcarenite, grayish buff; slabby; thin-bedded; medium to

finely crystalline.

3.3 ft. Calcarenite, light buff; weathers gray; massive; contains colonial corals and crinoid columnals.

9.8 ft. Sandstone, buff to reddish brown; weathers olive-gray; massive; fine-grained; micaceous; faint cross-bedding; phosphate nodules at the base. This is the basal unit of the Atoka formation.

130.3 ft. = Total measured thickness of the Atoka formation.

APPENDIX K

MEASURED SECTION OF THE ATOKA FORMATION EXPOSED IN RAILROAD CUTS OF THE KANSAS, OKLAHOMA, AND GULF RAILWAY, SECTION 20, T. 19 N., R. 19 E., MAYES COUNTY, OKLAHOMA.

18.4 ft.	Covered to top of hill. Surface strewn with sandstone, buff to pink, fine-grained. This interval is part of the Georges Fork-Dirty Creek sequence.
1.5 ft.	Sandstone, rusty brown; fine-grained; gritty; non-calcareous; irregular bedding.
1.5 ft.	Clay, light rusty yellowish-tan to light gray, with carbonaceous streaks; lumpy.
5.3 ft.	Sandstone, dark olive-gray, with lighter greenish-buff irregular streaks resembling cobwebs; weathers light olive-buff; fine-grained; somewhat quartzitic in appearance; some flattened clay particles, approximately 0.2 to 0.5 inch in length, in the lower portion. Southward along the cut, the beds are more massive, and the upper part contains one bed 1.6 ft. thick.
0.5 ft.	Sandstone, light olive-gray; fine-grained; gritty; slightly calcareous; carbonaceous and rusty streaks in the lower 0.1 ft.
1.2 ft.	Limestone, steel-gray; sandy; finely crystalline; contains some black carbonaceous streaks and stringers. Upper 0.3 ft. is more ferruginous, and weathers grayish-red.
0.2 ft.	Sandstone, dark grayish-brown; fine-grained; slightly calcareous; fucoids on under surface.
3.1 ft.	Shale, dark gray; sub-fissile. Also thin uneven bedded, dark gray to brown limestones and fine-grained calcareous sandstones. The shale thickens farther south in the cut, and contains very calcareous dark gray siltstones containing much carbonaceous material and many *Taonurus* markings.

1.9 ft. Sandstone, olive gray, fine-grained, weathers brown with a case-hardened appearance. Top surfaces crowded with fucoid markings; reddish to maroon stains; non-calcareous.

3.0 ft. Sandstone, pinkish-buff; fine-grained; tiny pink specks.

2.8 ft. Sandstone, light olive buff with tiny reddish-purple specks and streaks; fine-grained; thin-bedded; slightly micaceous.

4.9 ft. to 15.9 ft. Clay and shale, olive brown, with maroon stains. Thickness increase is noted within about 50 yards distance along the railroad cut to the southwest.

2.0 ft. Sandstone, olive drab; fine-grained; uneven-bedded; non-calcareous.

2.1 ft. Covered (Clay or shale and thin irregular-bedded fossiliferous limestones.)

0.3 ft. to 2.3 ft. Limestone, light grayish-buff; algal and nodular; porous; very fossiliferous; contains some olive green shale particles. Has lateral extent limited to about 50 yards along railroad cut, from top of cut on northeast to the disappearance of the interval toward the southwest.

2.8 ft. Clay, buff; rubbly; fossiliferous. Upper 1.2 ft. contain calcareous and ferruginous, crusty, irregular-shaped fragments.

5.3 ft. to 8.0 ft. Siltstones and fine-grained sandstones, gray buff to olive buff; fairly massive; cross-bedded; somewhat micaceous; weather to a chalky, smooth surface. On the east side of the tracks the lower portion is a gray, argillaceous, somewhat fossiliferous, limestone about 1 ft. thick. This unit rests disconformably upon the Morrow limestone.

72.5 = Total measured thickness of the Atoka formation.

APPENDIX L

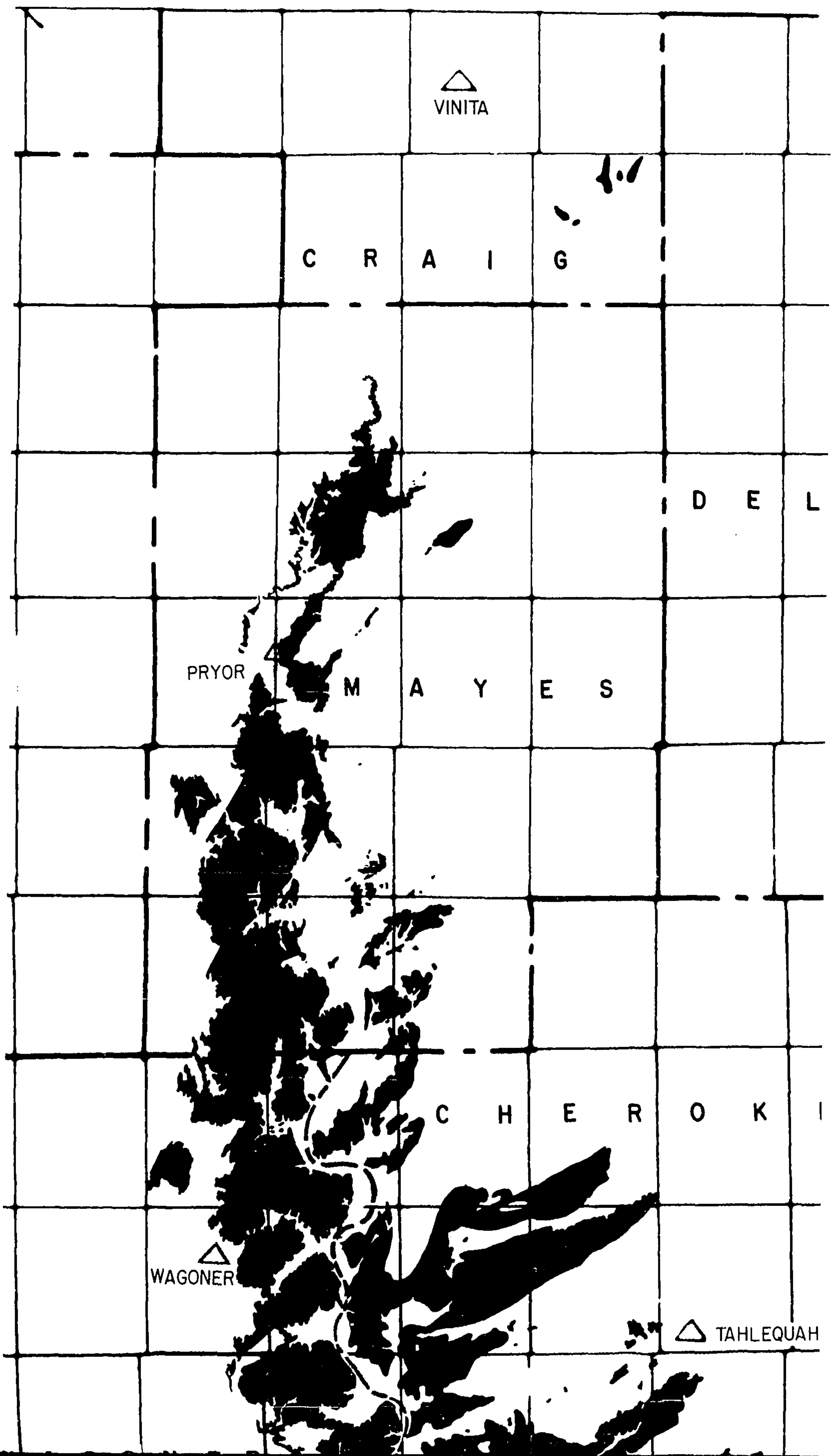
MEASURED SECTION OF THE ATOKA FORMATION IN CUTS OF THE RAILROAD SPUR AT THE OKLAHOMA ORDNANCE WORKS, SECTIONS 4 AND 5, T. 20 N., R. 19 E., MAYES COUNTY, OKLAHOMA.

6.0 ft.	Sandstone, gray to buff, with limonitic specks; fine-grained; micaceous. Lower 0.8 ft. highly decayed.
0.4 ft.	Limestone, gray to buff; fossiliferous.
0.2 ft.	Calcarenite with interstitial limonitic material.
1.5 ft.	Clay, reddish-brown.
0.5 ft.	Sandstone, white to purplish-gray. Disappears within a short distance along the cut.
6.7 ft.	Shale, black; sulfur yellow crust on bedding and joint surfaces.
0.2 ft.	Limestone, dark gray; lithographic.
1.7 ft.	Shale, black; sulfur yellow to bronze crusts on bedding and joint surfaces.
1.3 ft.	Sandstone, tan; medium-grained; thin-bedded; weathers rusty reddish-brown.
0.9 ft.	Sandstone, white to buff; fine-grained; weathers dirty grayish-brown, with manganese oxide stains.
3.7 ft.	Sandstone, light rusty-tan; fine-grained; thin-bedded; weathers light rusty-brown.
3.8 ft.	Sandstone, rusty-brown; limonitic cement; fine- to medium-grained, with clay particles; weathers light greenish-gray or buff; thin-bedded.
0.6 ft.	Shale, dark gray; sub-fissile.

6.2 ft. Conglomerate, rusty-brown, with subrounded pebbles of chert, limestone, shale, and clay.

3.4 ft. Sandstone, buff to olive buff; coarse-grained to conglomeratic. Pebbles of chert in conglomeratic portion are loosely cemented with iron oxide cement. Sandstone has large subangular quartz grains. This is the basal unit of the Atoka formation. The sandstone and conglomerate rest disconformably upon the Fayetteville formation.

37.1 ft. = Total measured thickness of the Atoka formation.



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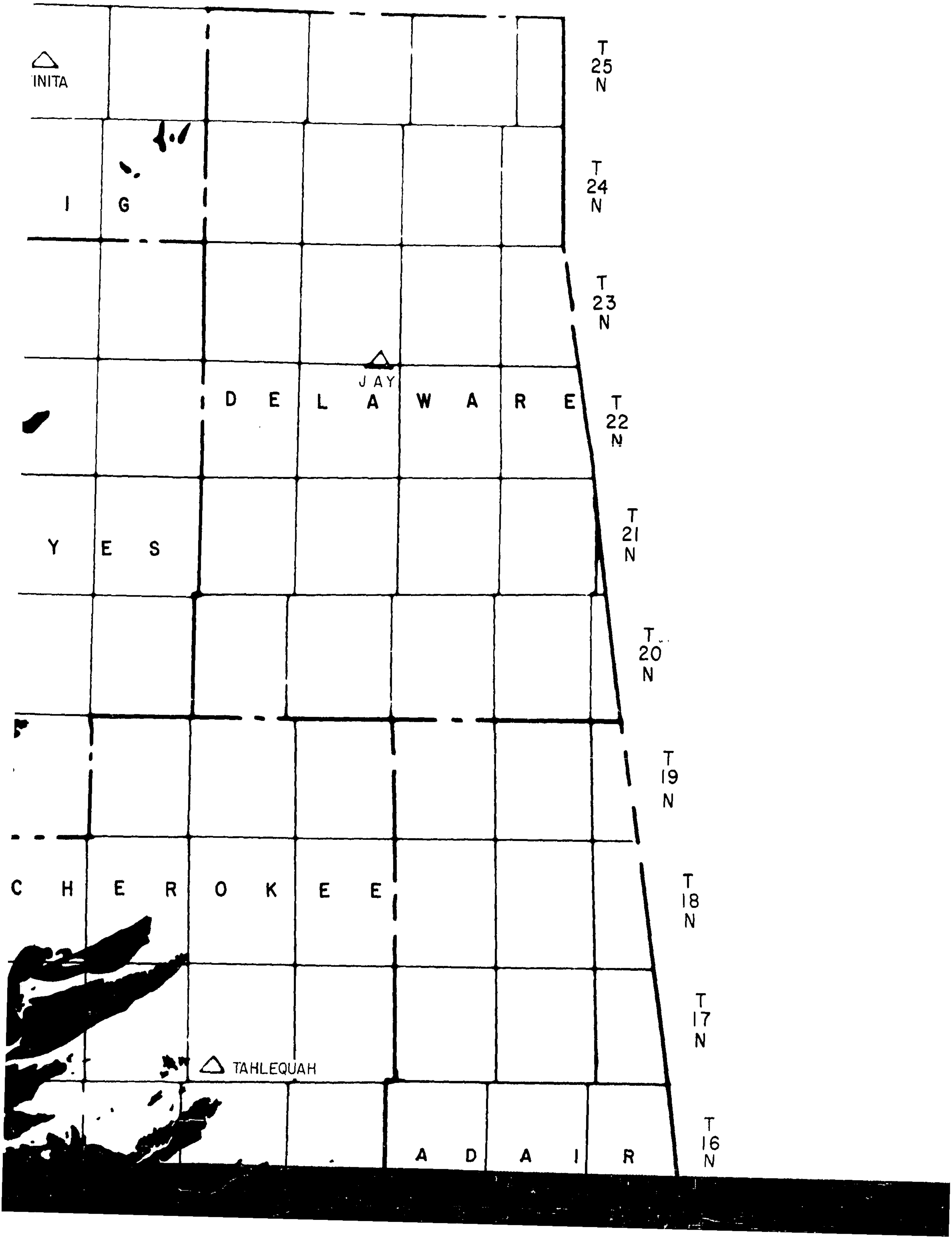
WAGONER
TAHLEQUAH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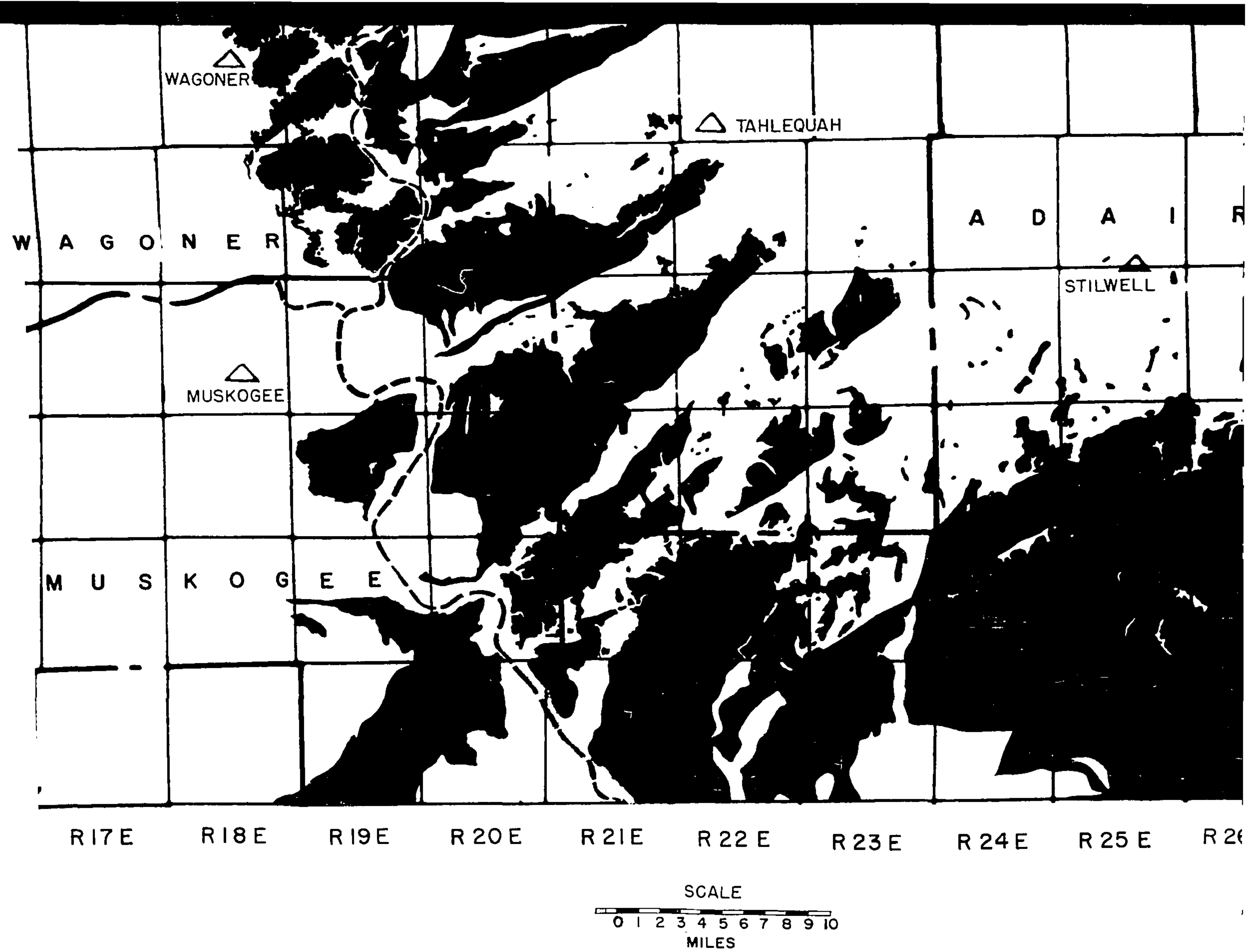

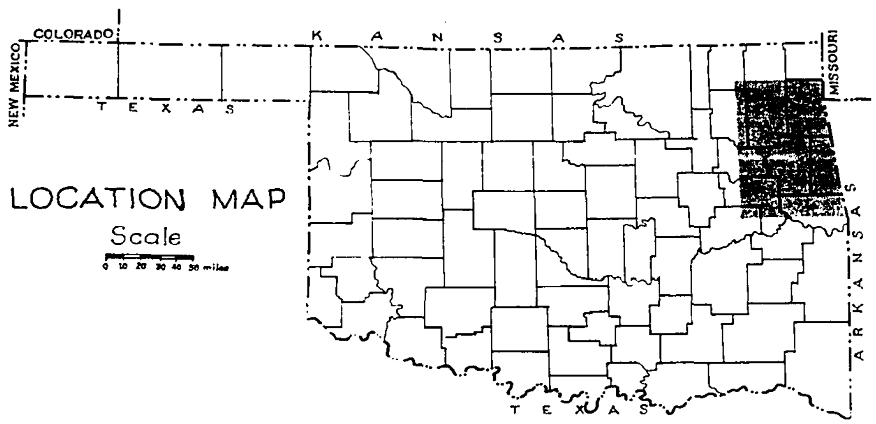

OUTCROP AF

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IN NORTHEASTERN

ADAIR, CHEROKEE, CRAIG, MAY

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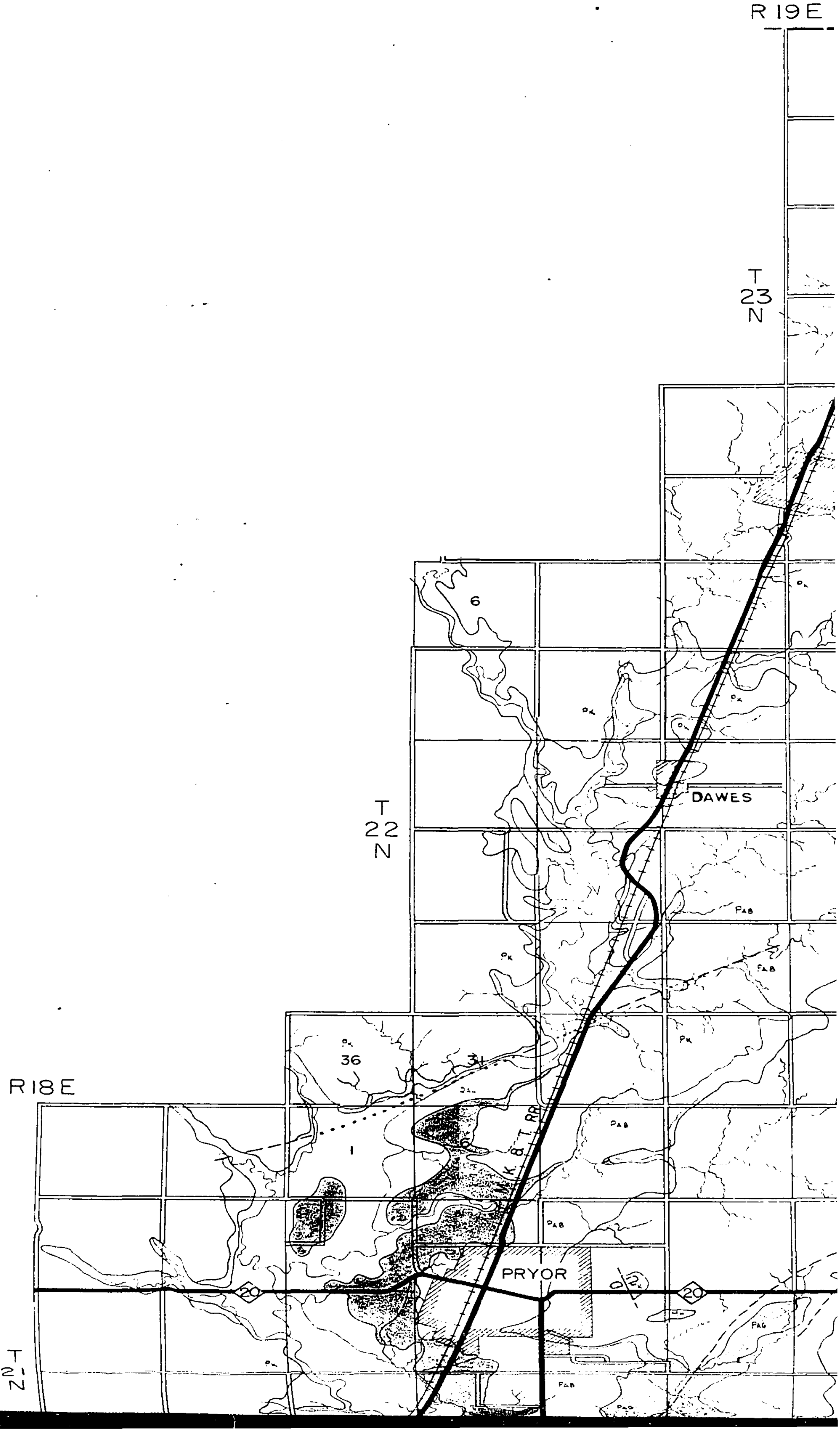
MAP I



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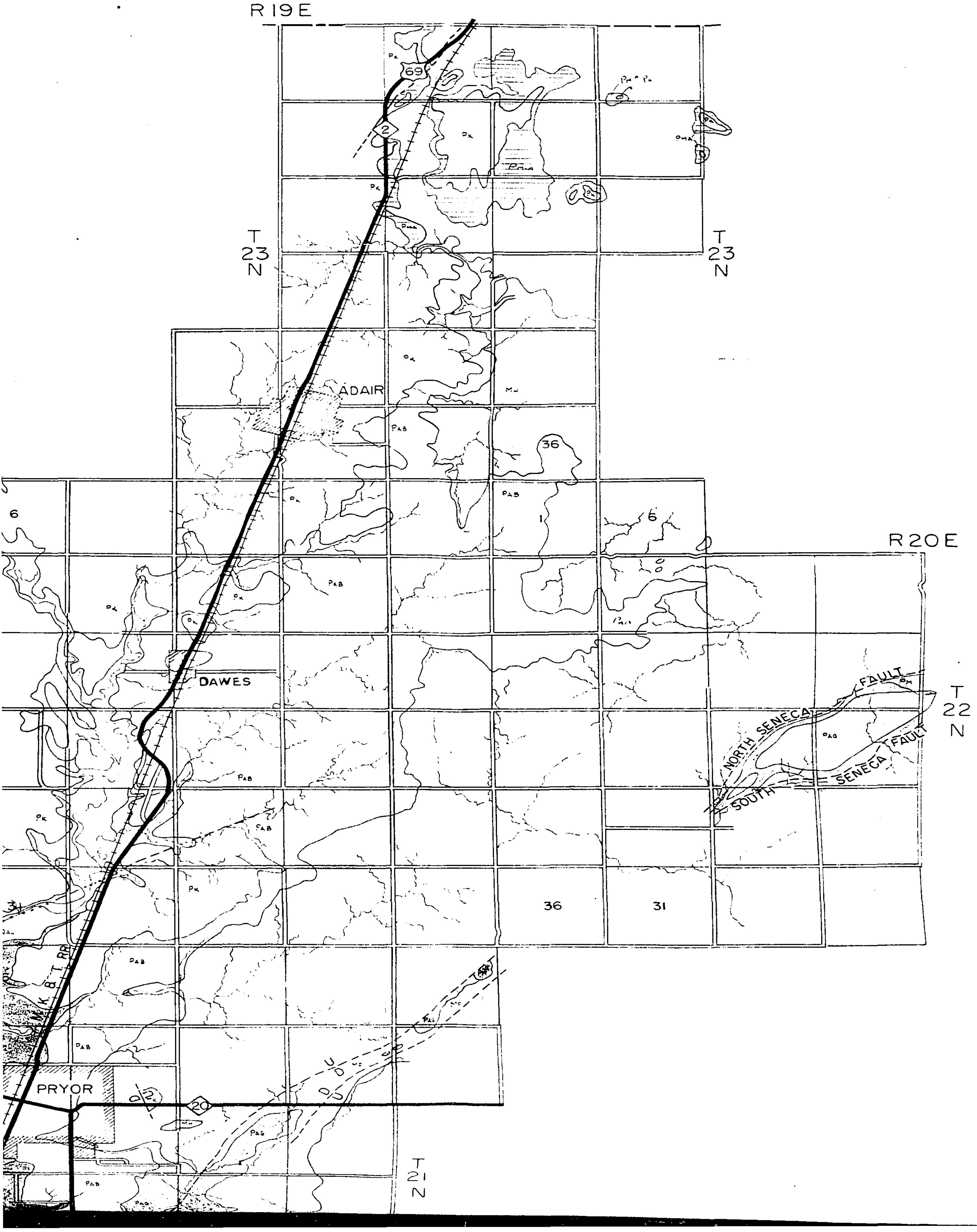
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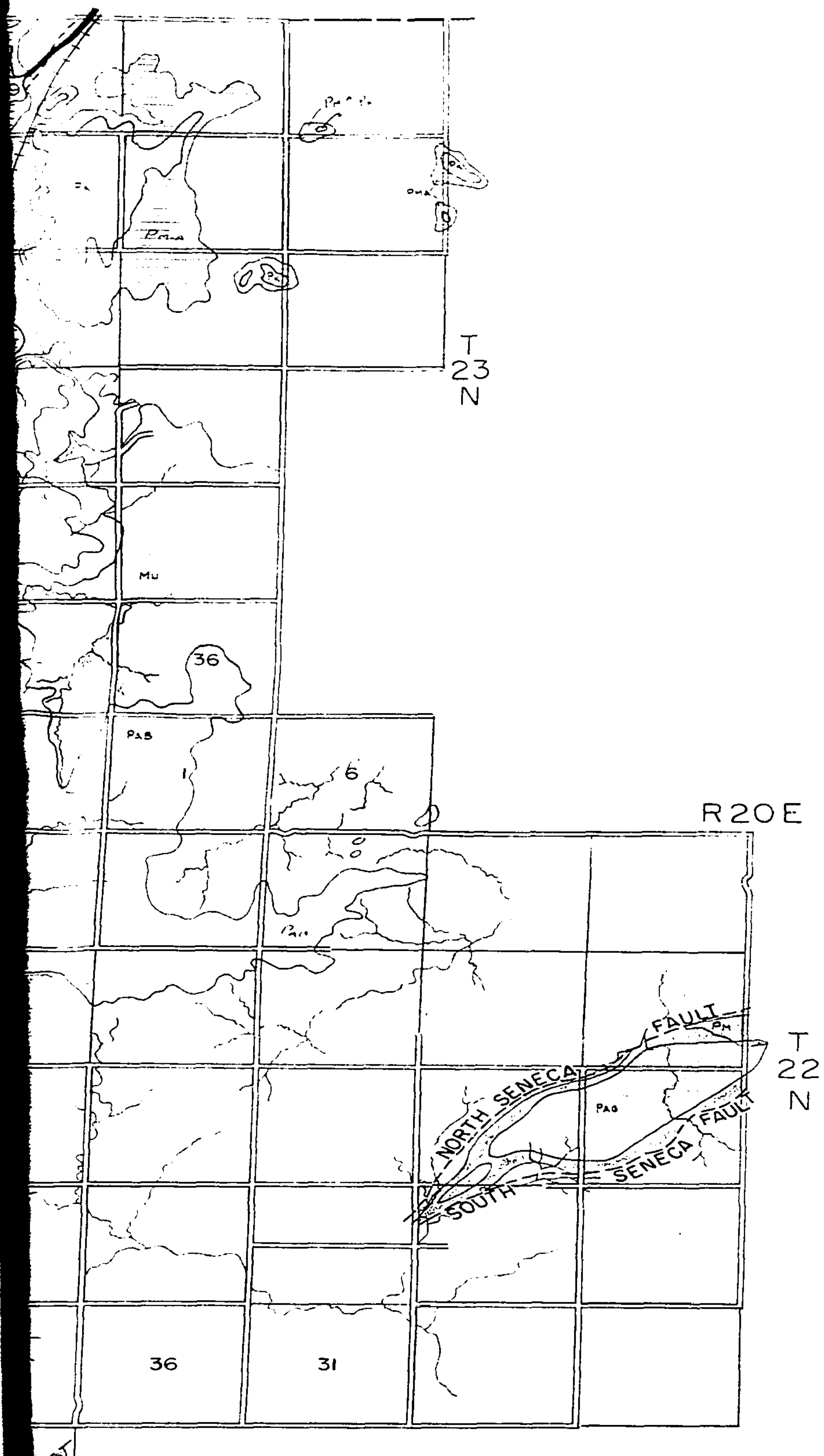
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AT

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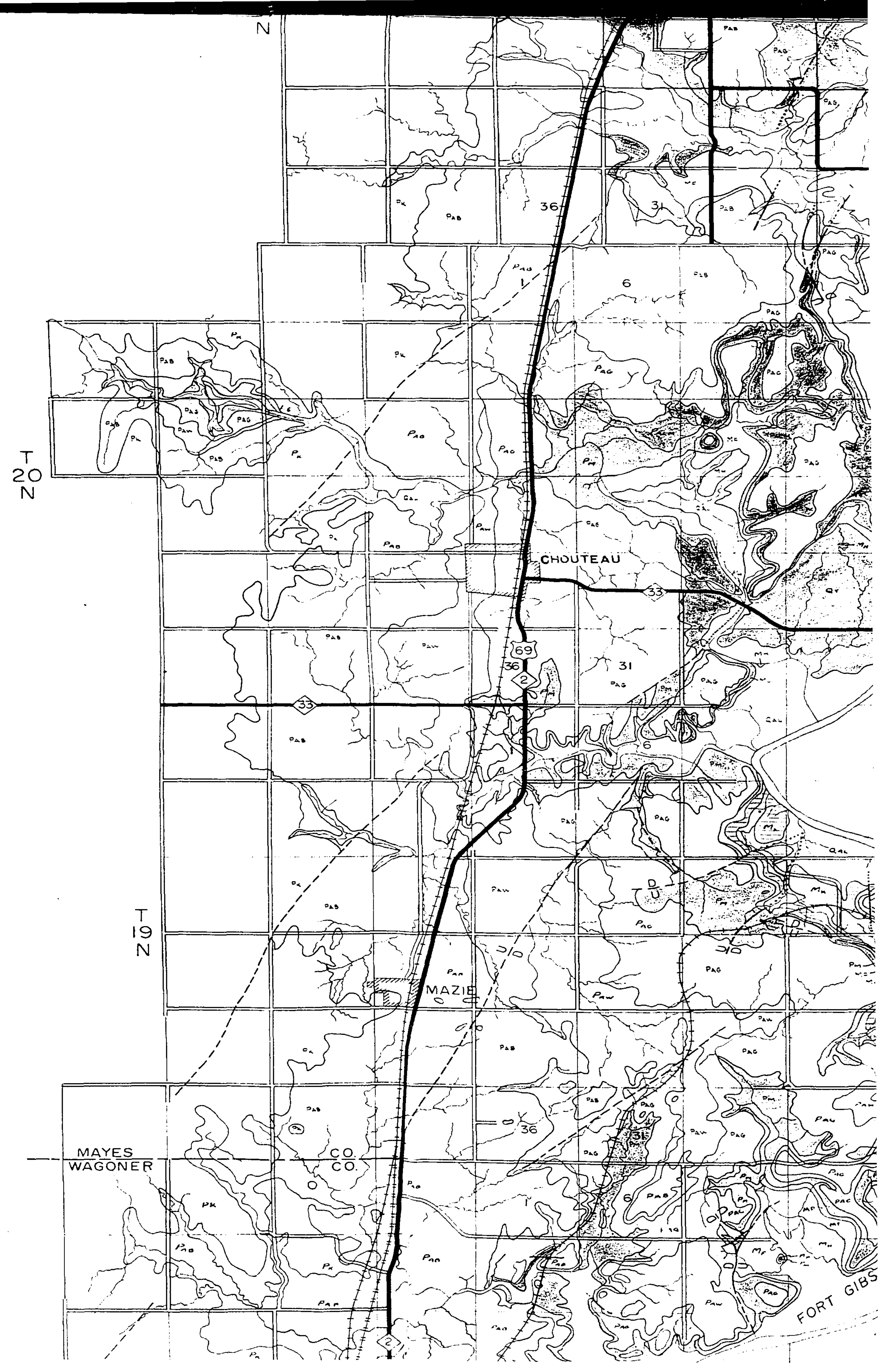
AREAL DISTRIBUTION
OF THE
SHELF FACIES
OF THE
ATOKA FORMATION
IN THE
OUTCROP AREAS
OF
WAGONER AND MAYES COUNTIES
OKLAHOMA

BY

JACK G. BLYTHE

1957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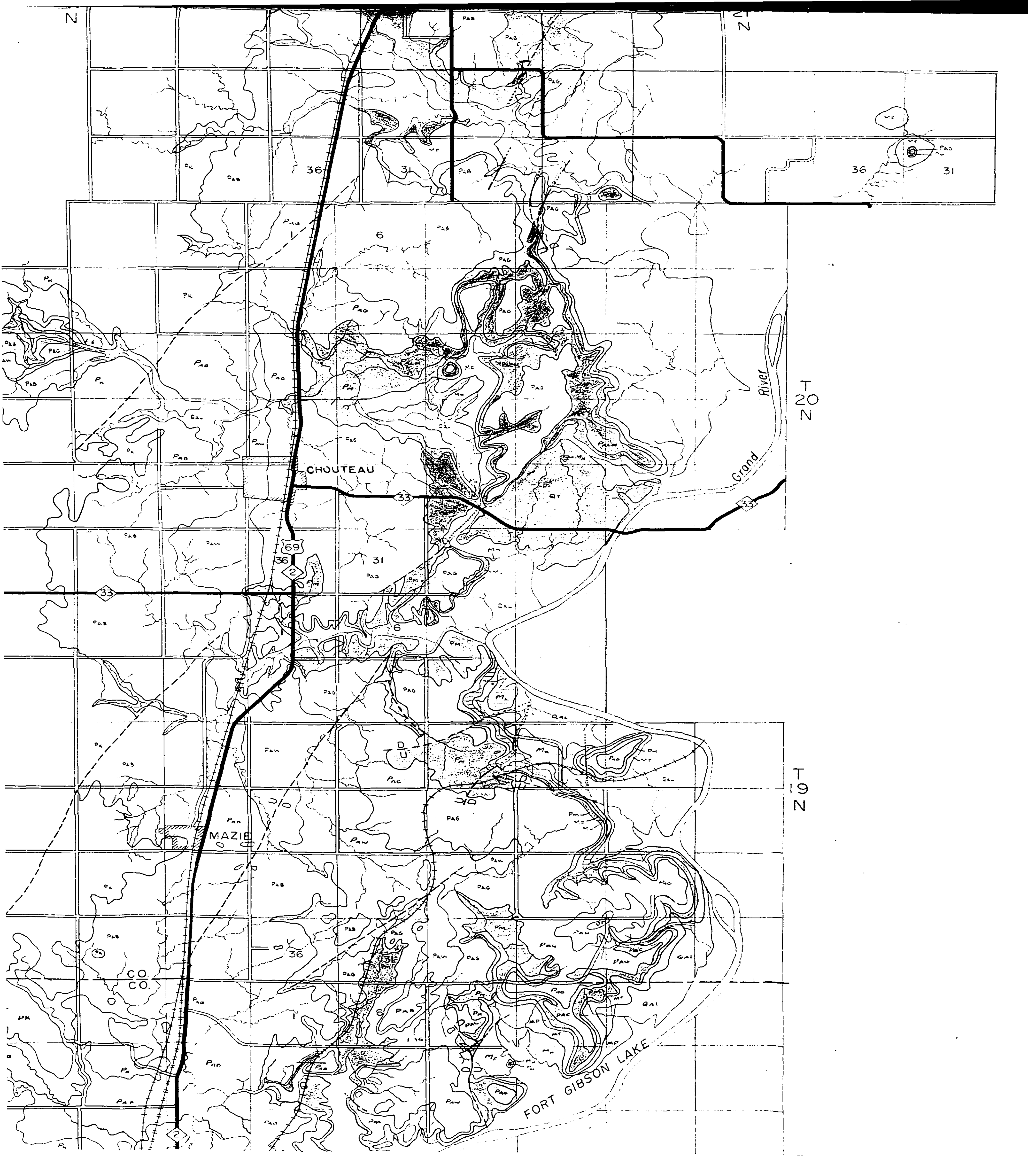
CHOUTEAU
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Grand River
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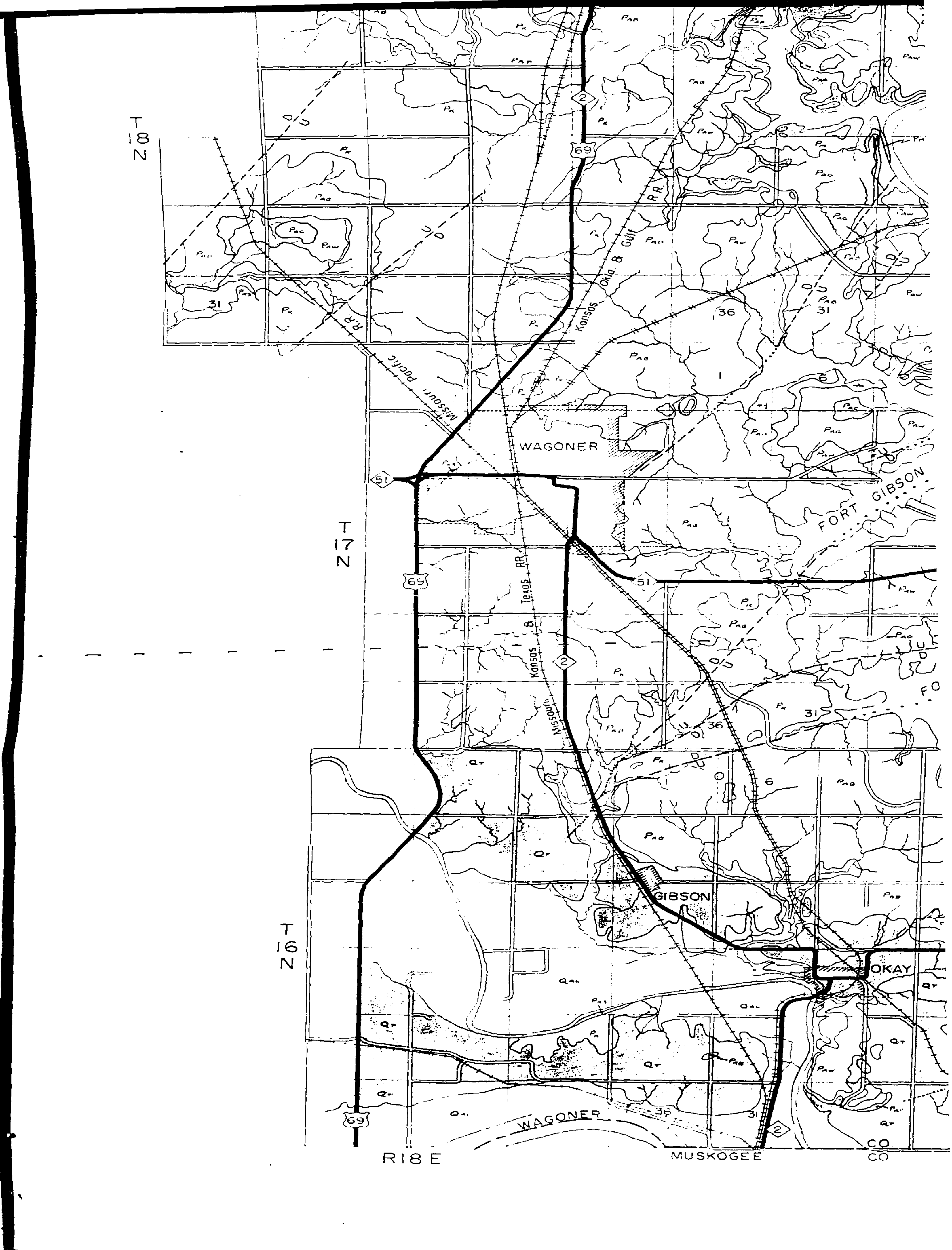
JACK G. BLYTHE

1957

0 1 2
MILES

EXPLANATION

QUATERNARY SERIES	QAL	ALLUVIUM
	QT	TERRACE MATERIALS
DESMOINESIAN SERIES	PKS	LOCAL RECOGNIZABLE EXPOSURES OF THE SPANIARD LIMESTONE MEMBER OF THE SAVANNA FORMATION
	PK	KREBS GROUP (PART) (UNDIFFERENTIATED HARTSHORNE (?), McALESTER AND SAVANNA FORMATIONS)
		ORANGE LINE MARKS THE APPROXIMATE BASE OF THE WARNER SANDSTONE MEMBER OF THE McALESTER FORMATION, AND THE THIN SHALES OF THE McALESTER AND/OR HARTSHORNE FORMATION BENEATH THE WARNER SANDSTONE
	PM-A	LOWER McALESTER AND/OR UPPER ATOKA SHALES, UNDIFFERENTIATED
ATOKAN SERIES (ATOKA FORMATION)	PAB	BLACKJACK SCHOOL MEMBER, AND OVERLYING SHALE
	PAW	WEBBERS FALLS MEMBER, AND OVERLYING SHALE
	PAG	GEORGES FORK — DIRTY CREEK SANDSTONES AND ASSOCIATED SHALES
	[illegible]	GOODY — POPE CHAPEL SANDSTONES
	[illegible]	LOWER & MIDDLE ATOKA MEMBERS, UNDIFFERENTIATED



T 18 N
T 17 N
T 16 N
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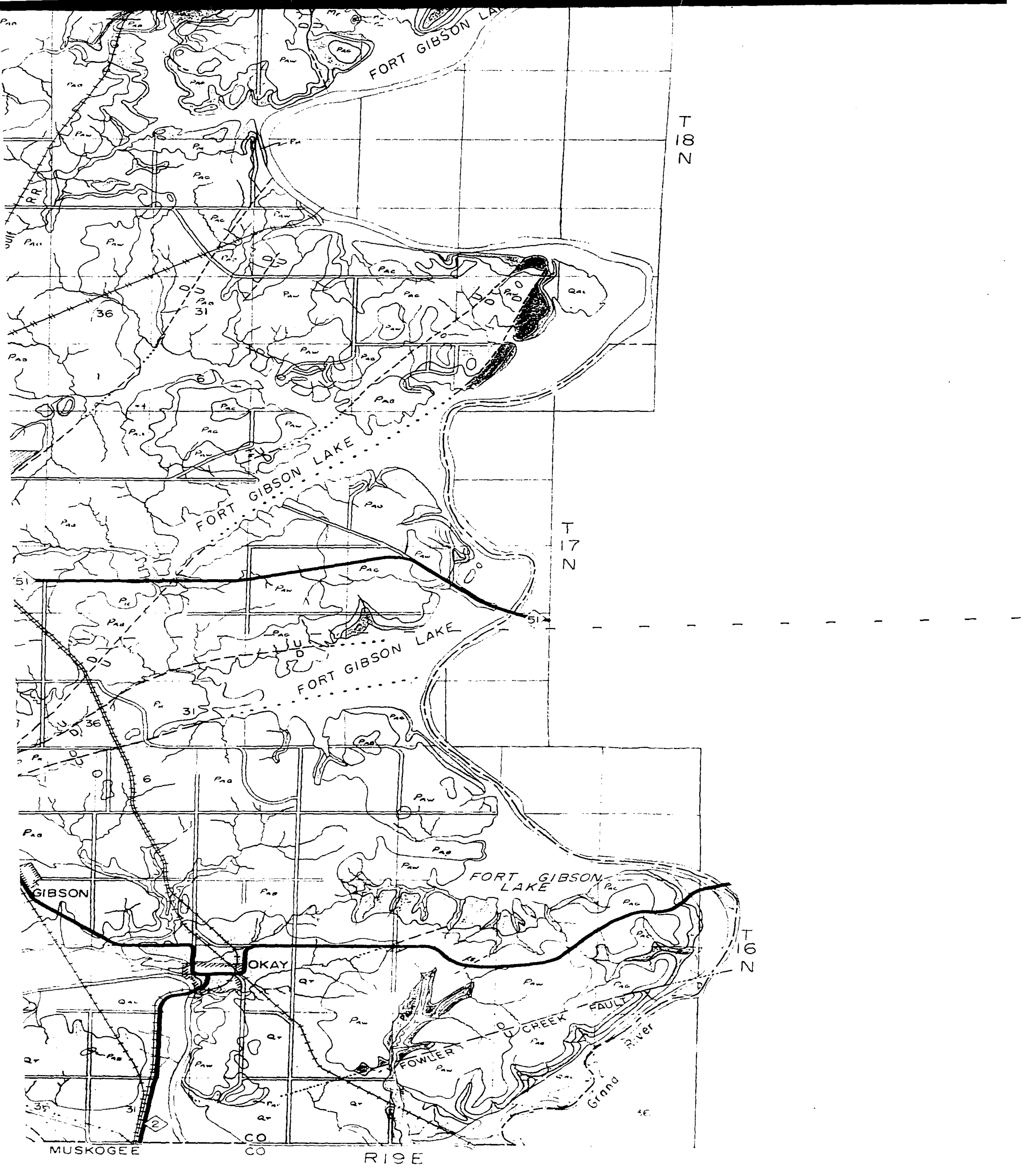
GIBSON
OKAY
FORT GIBSON
Missouri Pacific RR
Kansas Okla & Gulf RR
Missouri Kansas & Texas RR
69
2
51
R18E
WAGONER
MUSKOGEE
CO
CO



FORT GIBSON LAKE
FORT GIBSON LAKE
FORT GIBSON LAKE
FORT GIBSON LAKE
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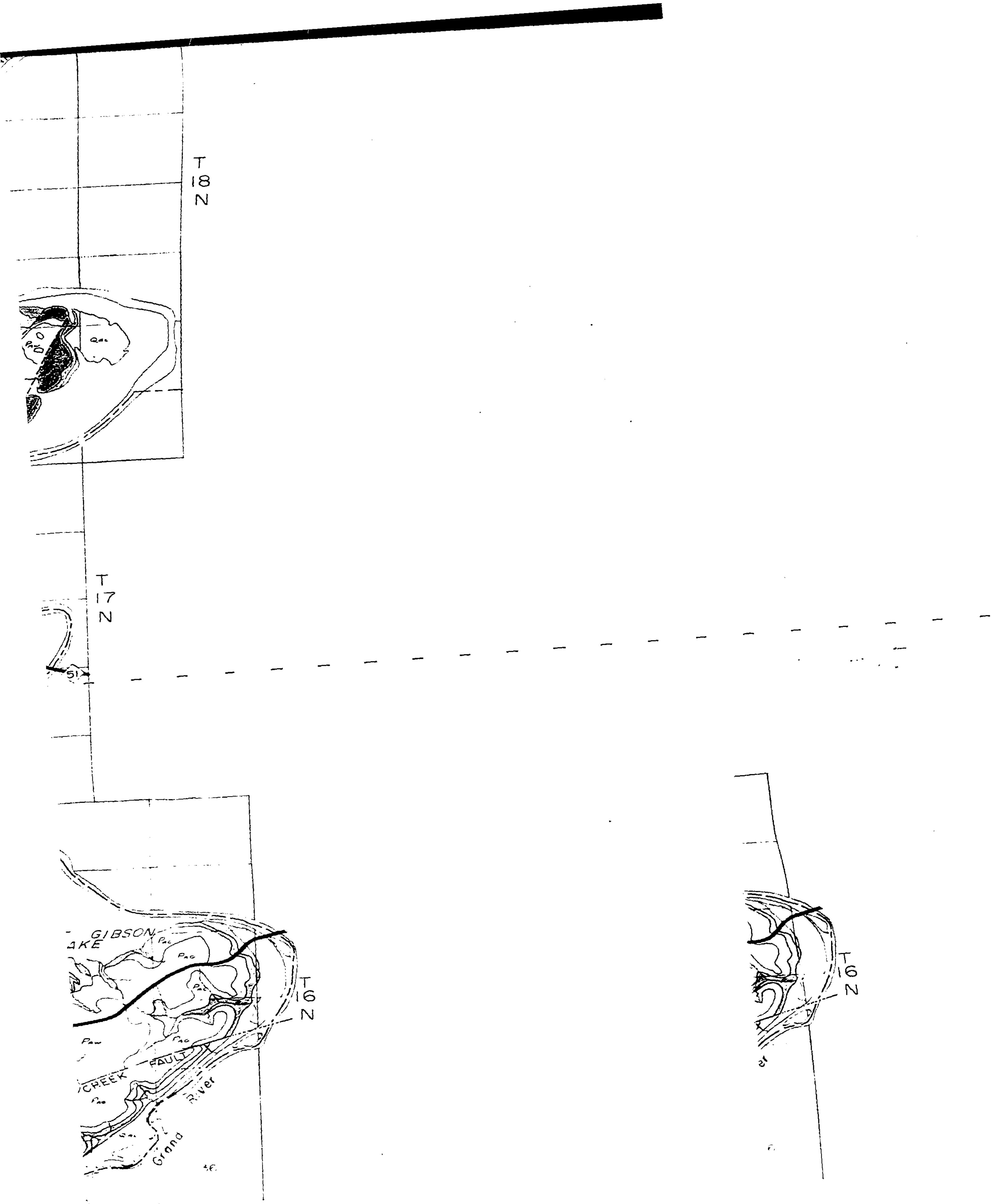
Grand River
MUSKOGEE CO
CO
R19E


T 18 N
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GIBSON
AKE
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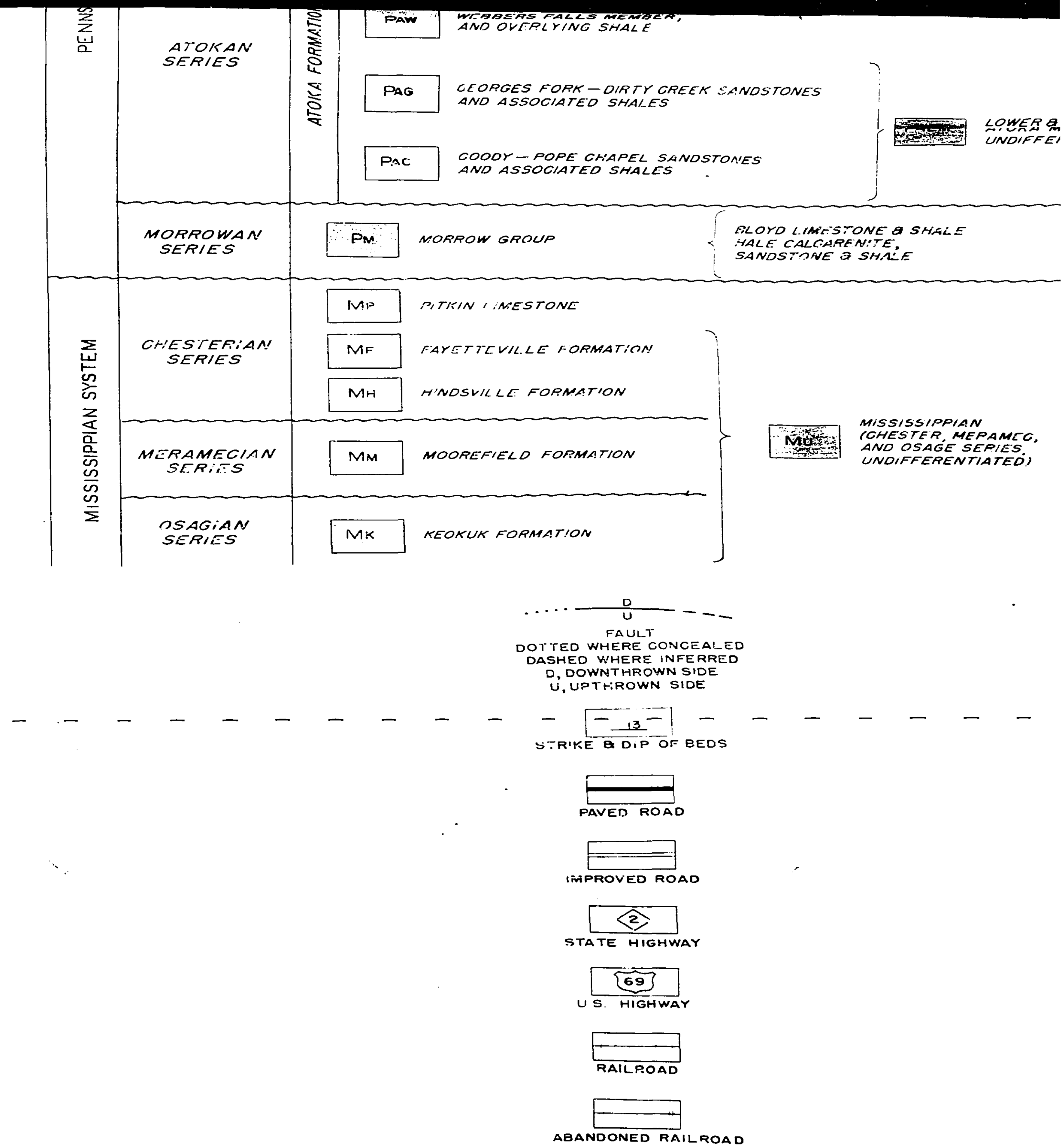
FAULT
River
Grand
T 16 N


MISSISSIPPIAN SYSTEM
ATOKAN SERIES
ATOKA FORMATION
AND OVERLYING SHALE
PAG
GEORGES FORK — DIRTY CREEK SANDSTONES AND ASSOCIATED SHALES
PAC
COODY — POPE CHAPEL SANDSTONES AND ASSOCIATED SHALES
MORROWAN SERIES
PM
MORROW GROUP
BLOYD LIMESTONE & SHALE
SANDSTONE & SHALE
CHESTERIAN SERIES
MP
MF
FAYETTEVILLE FORMATION
MH
HINDSVILLE FORMATION
MERAMECIAN SERIES
MM
MOOREFIELD FORMATION
OSAGIAN SERIES
MK
KEOKUK FORMATION
MISSISSIPPIAN (CHESTER, MERAMEC, AND OSAGE SERIES, UNDIFFERENTIATED)
D
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DASHED WHERE INFERRED
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U, UPTHROWN SIDE
13
STRIKE & DIP OF BEDS
PAVED ROAD
IMPROVED ROAD
2
STATE HIGHWAY
69
U S. HIGHWAY
RAILROAD
ABANDONED RAILROAD

MAP 2

ATOKA FORMATIO

PAW — WEBBERS FALLS MEMBER, AND OVERLYING SHALE

PAG — GEORGES FORK — DIRTY CREEK SANDSTONES AND ASSOCIATED SHALES

PAC — COODY — POPE CHAPEL SANDSTONES AND ASSOCIATED SHALES

LOWER & MIDDLE ATOKA MEMBERS, UNDIFFERENTIATED

PM — MORROW GROUP — BLOYD LIMESTONE & SHALE; HALE CALCARENITE, SANDSTONE & SHALE

MP — PITKIN LIMESTONE

MF — FAYETTEVILLE FORMATION

MH — HINDSVILLE FORMATION

MM — MOOREFIELD FORMATION

MK — KEOKUK FORMATION

MU — MISSISSIPPIAN (CHESTER, MERAMEC, AND OSAGE SERIES, UNDIFFERENTIATED)

D
U

FAULT
DOTTED WHERE CONCEALED
DASHED WHERE INFERRED
D, DOWNTHROWN SIDE
U, UPTHROWN SIDE

13
STRIKE & DIP OF BEDS

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IMPROVED ROAD

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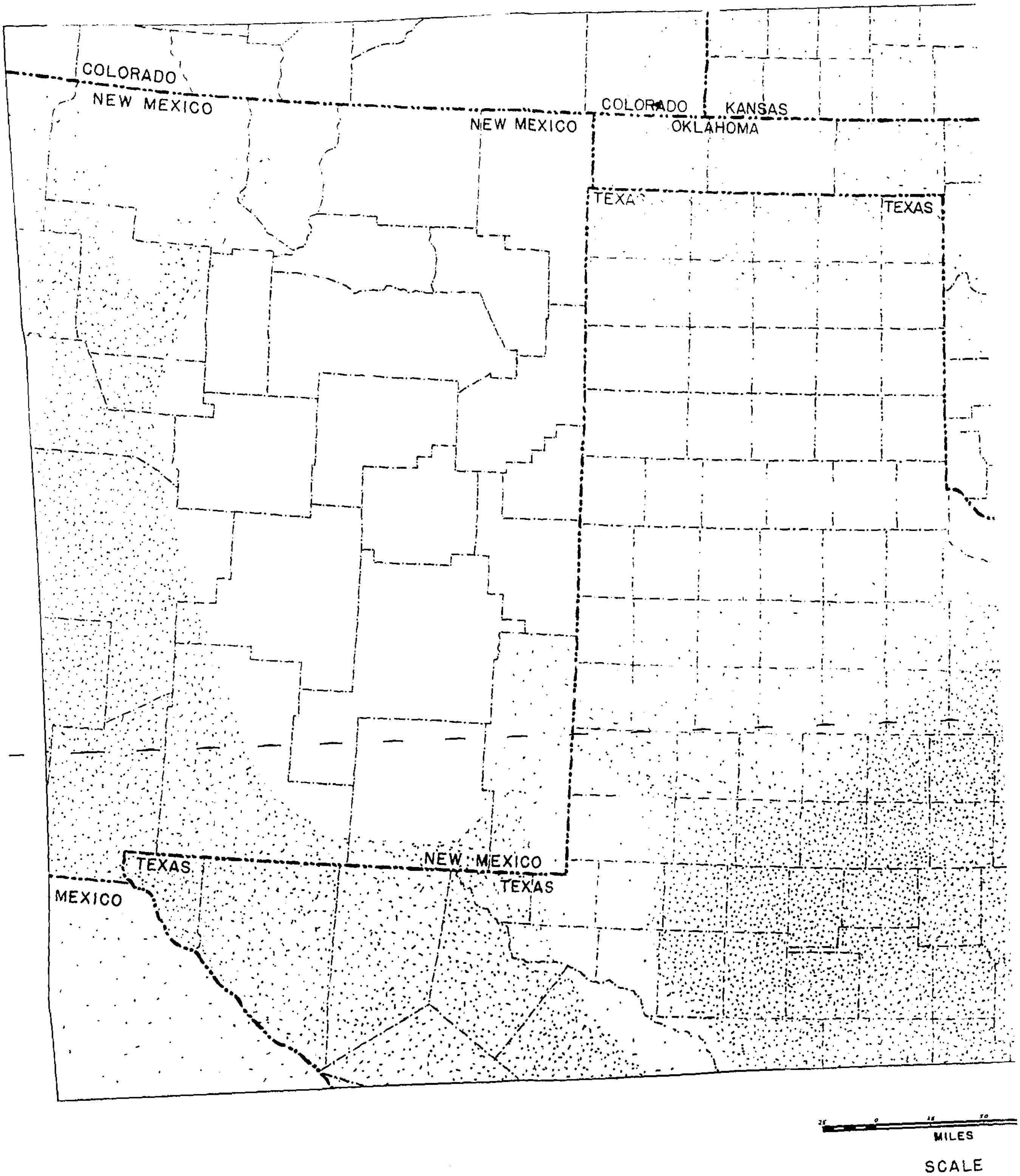
U S. HIGHWAY

RAILROAD

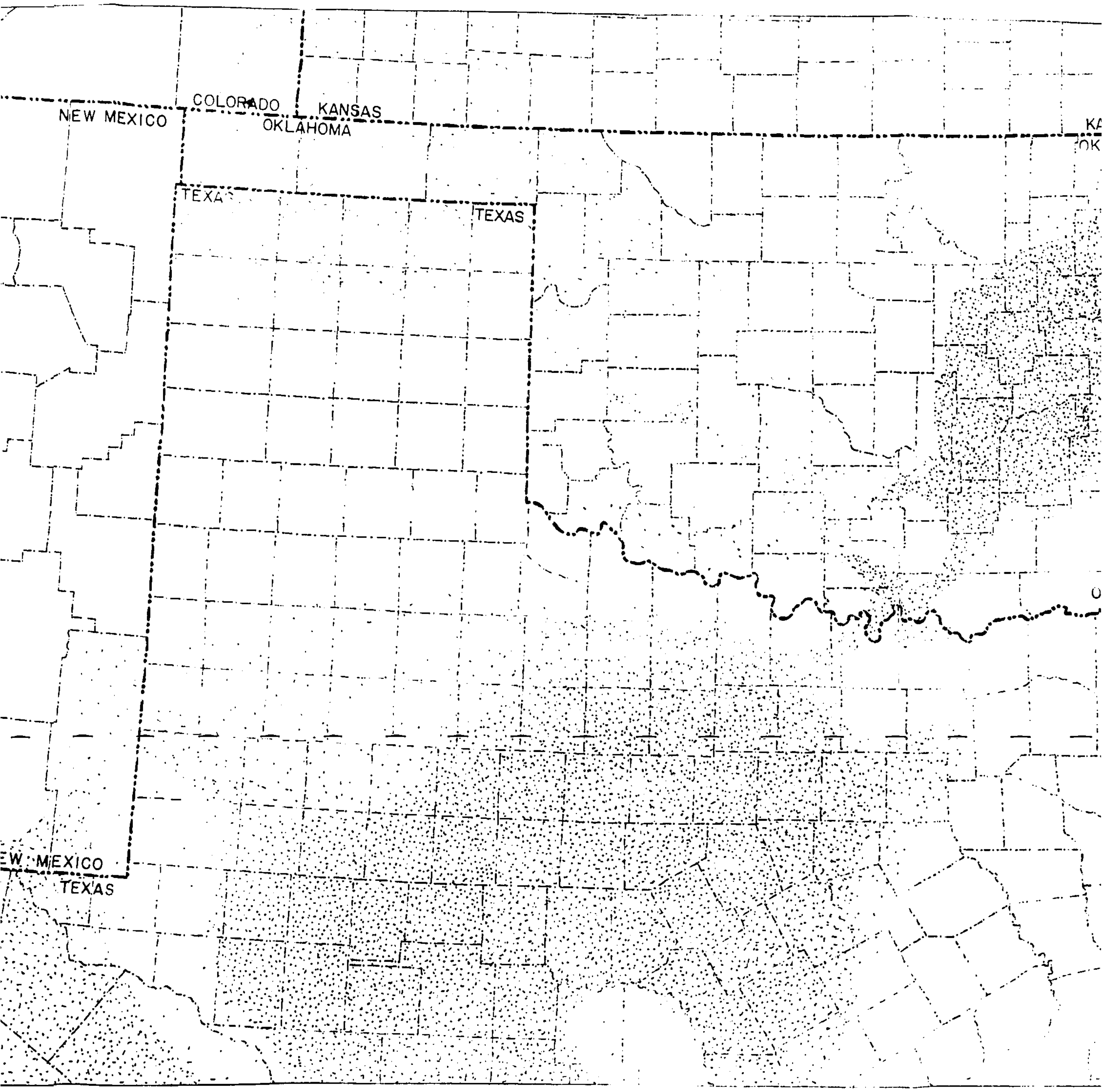
ABANDONED RAILROAD

MAP 2



POSTULATED EXTENT OI
IN
SOUTHWEST - CENTRAL U

MAP 3

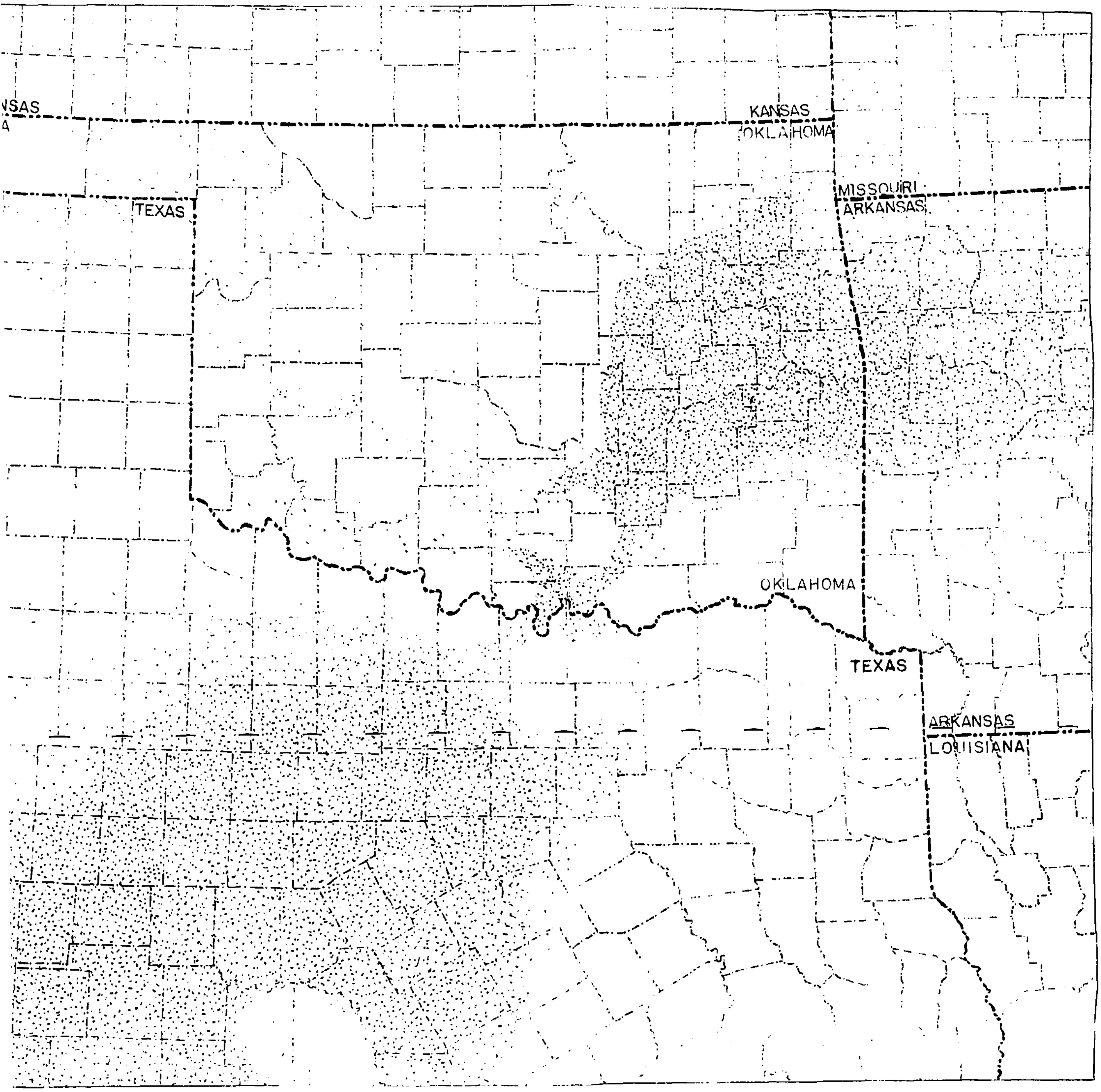


SCALE

STIPPLING INDICATES A
OCCUPIED BY ATOKAN S
OF STIPPLING IN AN ARI
CONCERNING THE FORM
SEA IN THAT AREA.

POSTULATED EXTENT OF ATOKAN SEAS IN SOUTHWEST - CENTRAL UNITED STATES

MAP 3



MILES

SCALE

STIPPLING INDICATES AREAS PRESUMED TO HAVE BEEN OCCUPIED BY ATOKAN SEAS. DECREASE IN THE DENSITY OF STIPPLING IN AN AREA INDICATES SOME UNCERTAINTY CONCERNING THE FORMER PRESENCE OF THE ATOKAN SEA IN THAT AREA.

ED EXTENT OF ATOKAN SEAS
IN
T - CENTRAL UNITED STATES

JACK G. BLYTHE

MAP 3